OIL FIRING FOR KITCHEN RANGES

E.C.BOWDEN SMITH

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OIL FIRING FOR
KITCHEN RANGES AND STEAM BOILERS

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FOR KITCHEN RANGES
AND STEAM BOILERS

BY

E. C. BOWDEN-SMITH, M.I.Mech.E.

LATE EGYPTIAN CIVIL SERVICE

AUTHOR OF
'THE EFFICIENCY OF PUMPS AND EJECTORS,' 'INVENTION:
AN ELEMENTARY ANALYSIS,' ETC., ETC.

NEW YORK
D. VAN NOSTRAND COMPANY
Eight Warren Street
1920

Printed in Great Britain

NOTE

The principal object now in view is to give a brief description of the combustion of heavy residues or fuel oil in a cooking range for culinary purposes.

Some general remarks on the production of crude petroleum and fuel oil, together with other information relating thereto, is included, as, comparatively speaking, the average householder or hotel proprietor knows little or nothing of oil for firing purposes.

Previous to the war, fuel oil had not been used in the kitchen as far as the author is aware, and it was entirely due to the great scarcity and high cost of coal, brought about by war conditions, that means were devised for firing kitchen ranges with similar residues to those that are used for firing purposes in the furnaces of steam generators.

There are many excellent liquid-fuel burners on the market for steam-raising and other purposes, but neither in design nor method of application do they conform with the exacting requirements of the domestic kitchen, in simplicity, reliability, cleanliness, and range of power.

For the kitchen range, a burner that will give a continuous flame of small dimensions is a necessity. For successful firing with residues of the highest viscosity, such as are used in oil-producing countries, the arrangements for feeding the burner with a constant flow of oil are of nearly as much importance as the burner itself, and it must be borne in mind that when the apparatus illustrated was devised, European resources were not available owing to war conditions. The success attained with the type of burner described for the kitchen range naturally led to the development of a large size for boiler furnaces, and examples of their application are also included.

E. C. B.-S.

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OIL FIRING FOR KITCHEN RANGES AND STEAM BOILERS

I

DOMESTIC FIRING AND THE COMBUSTION OF FUEL OIL, ETC.

SCARCITY OF FUEL.

The Great War has been responsible for many new problems, not the least of which has been the supply of fuel for domestic and industrial purposes, especially in those countries which have been accustomed to import coal from overseas. Even in countries possessing ample coal supplies the shortage of labour and transport has inflated prices to such an extent that liquid fuel has been seriously considered as an alternative for purposes for which coal has previously been used without question.

The advantage of applying liquid fuel to steamships, locomotives, and power plants, etc., has been well known for years. It is purely a matter of supply and price compared to coal; but for culinary purposes, in ordinary kitchen ranges, even in oil-producing countries, the absence of the means of combustion has prevented its adoption.

Cheap firing is a necessity to civilisation, and there seems to be no reason why coal should not be supplemented by fuel oil to a much larger extent than is at present the case.

OIL STOVES.

In countries like Egypt, when the importation of coal for the civilian population ceased during the war, paraffin stoves, either of the wick or vaporiser type, superseded the kitchen range; but they are open to many objections.

Besides the expense of the paraffin when consumed in large quantities for cooking, the wick type easily smoke, combustion is imperfect, they are not cleanly in operation, and their capacity for preparing quantities of food at the same time is strictly limited. The vaporiser type, though giving a good combustion, become choked by the deposit of carbon in the vaporiser tube, and are even more limited in capacity. For these reasons the paraffin stoves are quite inadequate for the demands of the large consumers, such as clubs, hotels.

GAS FIRING.

Gas firing is without doubt the most economical, but cannot be used in the ordinary range, and special gas cookers must be provided, together with larger mains, but these pipes are also subject to internal deposit, and the leakage of gas from the street mains in some cities often amounts to a considerable figure. Again, many proprietors do not relish the idea of scrapping their kitchen ranges and hot-water installations.

The advantage of the kitchen range is that a fierce local heat can be produced, and large vessels of water can be brought to boil in a minimum of time. Again, in the culinary arts, the chef likes to have at his disposal a fierce fire for certain operations, though perhaps for a few minutes only.

Gas will give a temperature of about 850 deg. Fahr.; whereas liquid fuel will give between 2000 deg. Fahr. and 3000 deg. Fahr. After all, it must be remembered, the cooking is done over the fire, and not in the fire, and the greater the heat by conduction and radiation, the greater the heat available for cooking. The familiar kitchen range is the product of precedent and convenience for the work it has to do, and it is not only the scientific point of view, in applying new methods of heating to perform necessary daily tasks, that must be considered; but making such methods acceptable to tradition, and to the ingrained habits of generations. For instance, the essentials in the operation of cooking are: the method of firing; the apparatus used, and the staff who carry out the work; and the first demand is that in a given time it is possible to carry out a given amount of work to the satisfaction of those concerned.

Gas firing is, no doubt, scientifically and economically, the best, and should be installed in new establishments provided the conditions and price are satisfactory; but the era of the kitchen range is by no means over.

OIL FIRING.

For industrial purposes two tons of fuel oil is usually considered to equal three tons of coal, and the expense of handling is considerably less. The kitchen range is more wasteful in its consumption of coal than a steam boiler, and one ton of oil will equal two tons of coal, provided the means of combustion is efficient. That is to say, fuel oil at £4 per ton will equal coal at £2 per ton, and still leave a margin of economy in transport and handling expenses. From this it is clear, whatever the advantages of using liquid fuel may be for industrial purposes, they are greater still for domestic use on the score of expense.

However, liquid fuel requires mechanical means to 'put it on the fire'—it cannot be thrown on the fire like coal.

There is something so simple in putting a shovelful of coal on the fire that it is not to be supposed popular prejudice will permit the majority of householders to suddenly adopt a new method of firing, even in countries where the economic advantage already exists. But when it comes to clubs, hotels, hospitals, and other large consumers, who either have to make dividends or account for their expenses, business will, no doubt, oust prejudice, when it is clear a great economy can be effected with less manual labour, but a little more care. Domestic duties carried out for generations cannot be easily eradicated, and it is only natural that proprietors and chefs should first oppose any radical alteration in such a vital section of their business as firing the kitchen range.

However, after a few weeks' operation there is no desire to return to coal dust, constant replenishing of the fire, indifferently heated ovens, or the complaints of visitors of tepid baths.

In all large establishments, where heavy cooking is constantly in progress, the range is invariably fired at its maximum capacity. That is to say, the maximum temperature that can be obtained is required, or the daily cooking would never be accomplished.

Herein lies the great value of substituting liquid fuel for coal in existing kitchen ranges. A greater number of vessels can be heated on the range at the same time, ovens maintained at the desired temperature without difficulty, and the fire controlled with a touch of the finger on the oil regulator.

This question of sufficient heat weighs more with proprietors than anything else. Though engineers may smile at such doubts, the proprietor views the matter from the heating powers of his gas fires and oil stoves, and is seldom convinced till he sees, by actual demonstration, the top of his range become cherry red in twenty minutes from lighting up. However, the cook soon discovers that he can regulate his fire to a nicety, and appreciates the boon of having ample reserve heat, in place of the constant efforts to keep up the temperature with coal firing.

FUEL OIL.

Everyone is familiar with 'petroleum' in the form of paraffin for illuminating purposes; but to the ordinary householder and hotel proprietor fuel oil is an unknown product, though it has been used for industrial and marine purposes for many years. Therefore it is as well to set down a few remarks on the nature of this product and its supply, before describing this system of burning fuel oil for domestic and industrial purposes. The consumer must, not unnaturally, assure himself of being able to obtain a constant supply before adopting it as a substitute for coal.

In England, liquid fuel can hardly compete with coal, but overseas, in oil-producing countries, and the Far East, there is a wide field for its extended use.

Like coal, petroleum is composed of carbon and hydrogen. Concerning its origin and formation little is known; but liquid hydro-carbons of almost identical composition can be distilled from organic matter, peat, lignite, and bituminous coal. Petroleum deposits are widely distributed over the earth's surface; but those at present worked are for the most part in tropical or semi-tropical countries. These deposits are found in porous rock formations, termed oil sands, and are located by sinking wells, where favourable geological conditions exist, if not from actual surface indications. However, the exploitation of an oil-field is the most uncertain of all undertakings, and until extensive drilling has taken place, which has proved the existence of the mineral in large quantities, it is never safe to assume that payable deposits have been located.

BORING FOR OIL.

Originally oil-wells were sunk by hand, but at the present day some form of percussion or rotary drill is invariably made use of.

Boring for oil is carried out in a very similar manner to sinking an artesian or tube well for water. If the strata through which it is desired to sink consists of hard deposits, the rotary drill is employed. This apparatus is provided with a hollow bit, and produces a core as the tool grinds its way downward by rotary action. By this means holes may be sunk to great depths through the hardest materials. In many localities the percussion type is used. Briefly, this consists of a tripod or suitable headgear, from which is slung by means of a pulley and steel rope a heavy iron bucket provided with a cutting edge and flap valve, or independent 'bits' of various design can be attached to suit the nature of the soil to be worked. A steel tube is set up vertically in the ground beneath the suspended tool, which is dropped by gravitation, and raised by the interposition of a lever. If the boring is to be of some depth, as they usually are in drilling for oil, a steam winch is used for raising and lowering the gear. As the 'bucket' or 'hollow bit' is alternately dropped and raised, it gradually works its way downward, and the tube or 'well casing' in which it works sinks into the ground. These tubes are made in convenient lengths, of about ten feet, and as they are provided with threads and sockets, can be screwed into each other as the operation of sinking proceeds. To screw on a new length, the sinking tool must be completely withdrawn.

If the soil is of a stiff, adhesive nature, it is often necessary to grip the head of the tube with wood clamps, on which weights are placed, while men with levers rotate the whole tube to assist its sinking. Literally speaking, the operation is simply punching a hole in the ground, the steel tubes preventing the soil closing the hole, and at the same time providing a guide for dropping the tool by gravitation.

With each blow of the sinker, the loosened soil passes through the flap valve, and is brought to the surface every ten or fifteen minutes, to be disposed of. If a solid ‘ bit ’ is used for hard ground, this has to be replaced by the hollow sinker or ‘ bucket ’ to remove the broken soil. In dry ground water has to be poured down the tube to assist the operation. These well casings may be from four to eighteen inches in diameter, according to the depth it is proposed to sink. Oil may be struck from one hundred to three thousand feet below the surface. Indications of a strike are often preceded by the discharge of gas, when necessary precautions are taken for capping the tube to control the oil, which may spout many feet into the air. Such wells are known as ‘ gushers,’ but sooner or later they cease to discharge, and either new wells have to be sunk, or means adopted for pumping the oil to the surface. If no oil is struck, or the well is no longer required, the casing is withdrawn by means of screw-jacks placed beneath the wood clamps used for sinking. It is, however, sometimes possible to withdraw the tubes by means of powerful chain blocks. Oil-wells are usually sunk over a favourable area on a well-defined system, and a survey of the ground is first made, before locating the sites of the proposed borings. As the sinking proceeds, a careful record is kept of the various strata passed through, and the depth at which it is located, as it is from such information that the geologist is able to make valuable deductions, and predict the depth at which oil should be struck, and decide how far the well should be carried down.

If the well is too shallow the main reservoir of subterranean petroleum may not be tapped, while if the well is carried too deep, it may be flooded with salt water or otherwise rendered useless. Again, if wells are sunk too close together, they may interfere with each other, and heavy expense incurred with little result. Indiscriminate drilling for oil may seriously interfere with the productive capacity of a field, which is one reason why such work should be undertaken by a company with ample funds, and not by a number of individual prospectors with independent interests.

The capacity of an oil-field is an unknown quantity. Some have already passed their maximum production, but there are many others which have scarcely been tapped, and still larger areas where geological conditions favour the existence of the mineral. As the characteristics of an oil-field, both from surface and underground indications, become more easily recognised from experience, less time and money will be expended in sinking wells in unsuitable localities.

The United States of America have been by far the largest producers of petroleum. Russia, Mexico, Roumania, Austria, and Borneo have all furnished large supplies ; while Persia and Egypt have recently commenced to develop extensive deposits. There are also enormous beds of oil shales in Europe and America, and large deposits are now being worked in England, but so far the cost of extracting the oil has prevented competition with the petroleum found in the liquid state, though there is no doubt these shale beds are potential reserves of immense value, and the difficulties of extraction will no doubt be overcome, if it has not been done already. Though the extent of the world's supply is purely a matter of conjecture, there is no reason to anticipate a shortage for many years to come, especially in the case of fuel oil.

CRUDE PETROLEUM.

Crude petroleum—that is, the mineral which gushes from the tube well when the oil-bearing stratum has been tapped—can rarely be used for commercial purposes till it has been refined. Neither is it advisable, as the lighter constituents must first be permitted to evaporate and are consequently lost, and valuable by-products would be consumed instead of being extracted.

The crude oil often contains water, sand, and various chemical impurities which have to be separated from one another, and for this purpose it must be refined. Oil refineries are often situated on the sea-board, so that the products can be easily transported to any part of the world. The oil-field may be at a great distance from the refinery, in which case the liquid is forced through pipes perhaps a hundred miles in length, by powerful steam pumps, or shipped in tank steamers if the locality of the oil-field and the nearest refinery make this method the most economical.

At first sight these refineries appear to consist of dozens of huge circular iron tanks similar to gasometers, but they are, however, only used for storing the various grades of oil. Closer inspection reveals sheds and buildings containing countless steam pumps, air-compressors, networks of pipes, besides stores, offices, workshops, and the main distilling plant. It is in this distilling plant that most of the process of refining takes place.

Briefly, the principal features of such a plant may be said to consist of a series of huge boilers, each one at a lower level than its neighbour, and connected together by pipes controlled by valves. These boilers are heated, and the crude oil is charged into No. 1. When a certain predetermined temperature has been reached, the lightest constituents of the oil are given off, collected, and stored while the charge enters boiler No. 2. The process is repeated, a second quality of spirit extracted, and the charge enters a third boiler. Another grade is distilled, and so the process proceeds till all the spirits and paraffin oils have been extracted from the petroleum.

Now it is the residue from this distilling process that is called fuel oil, the liquid with which we are concerned for firing purposes. These residues have a much greater heating power than coal: herein lies their value. But they cannot be burnt like coal in a kitchen range, and herein lies the reason of their neglect for domestic use. Fuel oil is brown in colour, of a viscous, clinging nature, and below certain temperatures some qualities are difficult to handle owing to the refractory nature of the ingredients. It is also known under a variety of names, such as 'residuals,' distillates,' 'astaki,' and 'mazout,' according to the country from which it is derived, and it also varies in composition.

Some oils have what is known as an asphaltum base, and others a paraffin base. Residues from asphaltum oils have a high density, solidify easily, and usually contain a percentage of sulphur. If the sulphur content is above a certain figure, it is liable to damage tubes and furnaces when the oil is used for firing purposes. The presence of sulphur is easily detected, as the products of combustion will deposit a yellowish substance in the furnace.

Oils with a paraffin base are not of such a viscous nature, are less affected by exposure to air, and are easier to pump through pipes. Not unnaturally, the better residues from the fluid point of view are those which are transported to Europe, while the heaviest residues, which in some cases it would be impossible to pump on board ship in cold weather, are used locally.

It must not be thought, however, that petrol, paraffin, and fuel oil are the only products than can be obtained from crude petroleum. It is, indeed, one of the most remarkable minerals in existence, from the number of constituents and the variety of commercial products of which it forms the basis. Paraffin wax, journal oil, cylinder oil, candles, vaseline, or petroleum jelly, are all products in common use.

Some oil-fields produce petroleum with a higher percentage of petrol and paraffin than others, but sixty per cent. of residues is not uncommon. There are several qualities, all of which can be safely used for firing purposes, but the product from some fields has to be warmed in cold weather before it can be pumped through a pipe, owing to its viscous nature. This feature in no way detracts from its heating value.

COMBUSTION OF LIQUID FUEL.

In Great Britain the expense of liquid fuel in all forms, compared to coal, has, no doubt, retarded the development of the methods of combustion. Overseas, the consumer invariably looks to Europe for mechanical apparatus for such purposes, and has to accept what is placed upon the market. In one respect there is nothing simpler than to construct apparatus for the combustion of liquid fuel; in another, there is nothing more difficult than to combine reliability with efficiency in the process.

It is a fuel that is exceedingly easy to use economically with care in use; but, like all fluid products of value, can be easily wasted. When dealing with small quantities, such as used in a kitchen range, five per cent. or ten per cent. economy is not of much importance; but in large plants, consuming several tons per day, this amounts to a large figure per year.

It is true for marine purposes a high state of development has been reached, but by means which are quite unsuitable for domestic use—in fact, out of the question.

Though the application of fuel oil to the kitchen range does not evolve new discoveries, it entails a novel form of apparatus for reasons which will presently be apparent, when the existing methods of burning oil are described, and their limits explained.

The kitchen range is built for the combustion of coal, and to provide the most effective heating surfaces for cooking operations, such as boiling and baking, etc. To apply liquid fuel in place of coal, structural alterations in general design are not necessary or worth the extra expense. The apparatus should be applicable to the ordinary type of closed range.

The methods of combustion of liquid and solid fuel are radically different. With coal, a surplus of air and intermittent firing cannot be avoided. With oil, the air can be directed to where it is required, and firing is continuous and uniform.

For the work done the consumption of coal is enormous, even compared to coal used for steam-raising purposes, whereas the consumption of liquid fuel in proportion is much less, even in the primitive stage of development which it has already reached.

It is not only the efficiency of the fuel that is actually consumed, but the percentage that is either purposely or unavoidably wasted, that must be considered. Again, in drawing comparisons, the expense of transport, labour, storage, etc., must not be overlooked.

Like all other work accomplished by heat, which is power, the object is to obtain the maximum amount of work for the power employed—in other words, to use the heat to the best advantage.

The first essential to obtain this desirable end, is to have perfect control of the supply of fuel, and maintain an even temperature. Secondly, to accomplish the work to be done in the shortest time, so that the process of combustion need not be continued a moment longer than is necessary.

Now, as liquid fuel is fed into the furnace in a uniform stream, it is easy to regulate the supply on which the temperature of the furnace depends, and, as the oil has a much greater heating value than coal, and can be stopped at a moment's notice, a given amount of cooking can be accomplished in a shorter time with less waste of fuel.

Crudely stated, we throw coal on the fire and the atmosphere does the rest. The combustible properties of the fuel are distributed over the fire-bars, and automatically mix with the air. By arranging the furnace or fire-grate in which the fuel is burnt, so as to obtain a fierce draught, we hasten the process, higher temperatures are maintained, and more fuel is burnt per square foot of grate area—in fact, an increase in the power of the furnace.

Now, whether coal is burnt in a large kitchen range or under a boiler, it will be found that constant efforts are being made to obtain the maximum temperature under the conditions that exist. Thus we find the chef in the hotel keeps the top of his range red-hot, and forced draught for marine purposes becomes more and more the practice. In the first place, more cooking can be done in a given time, and in the second, more steam can be obtained from the boiler—that is, there is a higher rate of evaporation. As the combustion of oil produces much higher temperature, it is clear that both the range and the boiler can be of smaller dimensions to perform the same work. With few exceptions, it is more economical, from the fuel point of view, to carry on fierce combustion in one furnace, to produce a certain number of heat units, which can be converted into useful work, than it is to utilise two or more furnaces to give the same result. To burn liquid fuel economically, a higher temperature is required than for coal.

Like all other novel systems of extreme simplicity and reliability, the application of fuel oil to the kitchen range is looked upon by the consumer as a matter of course after a few months daily use, but such developments are not evolved without labour and expense and an exhaustive study of the subject. It is not so much the chemical composition of the fuel that must be analysed to construct mechanical means for its distribution, but the peculiar nature of the liquid, its creeping propensities and searching qualities at various temperatures, which render it so refractory in use.

The efficient combustion of fuel oil is in itself a science, and means can only be devised by approaching the matter from the right direction and first mastering those essentials on which good combustion depends. These essentials are distribution of the oil, temperature, and draught.

By distribution of the oil is meant not only the efficient pulverising of the liquid, but supplying the mechanical apparatus or burners with a constant and regular stream. As purchased on the market, fuel oil often contains foreign matter. It is of a heavy viscous nature, readily chokes small orifices, and, when exposed to a fierce heat, carbonises in contact with any substance, if the first stages of combustion have not already taken place. But these first stages of combustion depend upon maintaining a high temperature, and this temperature again depends upon the volume and means adopted of admitting air to the furnace.

The smaller the fire it is desired to maintain, the smaller the required flame, and the more difficult it is to ensure a constant uniform flow. The process of combustion is extremely rapid, and with the slightest cessation of the minute stream of oil, the flame is extinguished, the temperature falls, and there may be difficulty in rekindling the flame without applying a torch or lighting some inflammable material. Fuel oil is anything but inflammable; on the contrary, it is difficult to ignite at all when cold, and used to excess will put the fire out.

METHODS OF COMBUSTION.

There are three methods of combustion, which may be described as follows :—

1. Open hearth or atmospheric.
2. Vaporising the oil.
3. Atomising the oil.

The first of these systems consists of a series of shallow iron troughs, so disposed that the oil drips from one to the other, while being consumed. Under certain conditions, such as in camps for open-air cooking, it is effectual, but not efficient, and is accompanied by much smoke and carbonisation of the oil. For use in a kitchen range this system is out of the question.

2. The system of vaporising the oil is well illustrated in the Primus stove, and those especially constructed for using fuel oil do not differ in principle. Air pressure is maintained on the oil in a suitable vessel, and the vaporising tube surrounding the jet is so disposed that the flame automatically heats the oil to such a temperature that it is converted into gas before it issues from the nozzle of the burner. To light the burner a small quantity of spirit is placed in a metal cup, fixed below the vaporiser. This spirit, when lighted, will vaporise sufficient oil for starting purposes. This system is economical and clean, but all such burners are subject to internal deposit, and when fuel oils are vaporised the tubes become

choked and the burners inoperative. Experiment may produce improvements, but it is doubtful if the fundamental defects can be removed which limit the scope of its usefulness.

3. It is generally admitted that to burn fuel oil efficiently, it must be atomised—that is, pulverised and disintegrated into minute particles. To atomise fuel oil some agent or power must be employed. Of these agents there are three:—

(i) By means of pumps, which force the liquid through a small orifice at a high pressure, which causes the oil to be distributed in fine spray.
(ii) By means of a steam jet, acting as the pulverising agent.
(iii) By means of compressed air, acting as the pulverising agent.

Clearly neither the first nor second of these methods can be utilised with cleanliness or safety in a domestic kitchen. The only logical conclusion is to use compressed air as the atomising agent; and it has the unique advantage, in some cases, of serving a double purpose. Compressed air is both cleanly to use and safe to handle, and, as the volume required is small and the pressure low, there is not much difficulty, at the present day, in providing the means of compression. Various methods will be dealt with later on.

EARLY METHODS OF COMBUSTION.

Before proceeding to the technical description of the application of liquid fuel to the kitchen range, it will not be out of place to touch on some of the earlier methods of combustion.

Though at the present day there is only one method of burning liquid fuel in general use—that is, by atomisation—early inventors spent much time in trying to perfect other systems. Precisely why they neglected atomisation is not clear, as any crude apparatus will accomplish this, and as the first attempts were apparently made on steam boilers, the atomising fluid was available.

It may be that as the oil-fields were far removed from the centre of civilisation, men of science and learning did not at first turn their attention in this direction, and those who experimented failed to grasp the essential conditions necessary for good combustion.

In adopting mechanical means to perform a certain task, that task, which in this case is the burning of a viscous fluid, must be carefully studied from every point of view, and the properties of the substance we wish to handle analysed to ascertain its behaviour under varying temperatures and conditions. For instance, if original steam users had attempted to fire their boilers with a solid block of coal on the fire-bars, great difficulty would have been found in raising steam. It is absolutely necessary to disintegrate the fuel to admit the air for combustion and for the purpose of manipulation.

In the same way liquid fuel must be disintegrated, but even more so if fierce combustion is to be maintained. Such being the case, it is not to be wondered at that as little success was met with in trying to burn a mass of oil as there would be in trying to burn a block of unbroken coal.

The fact of the fuel being a liquid of an absorbent nature and capable of being easily vaporised, thus converting it into a gas which readily ignited, no doubt led early experimenters astray.

It is true by vaporisation a certain amount of success can be obtained, but it is a false clue, and its usefulness strictly limited. The residues of the liquid are inevitably left behind to accumulate, and the process of ‘choking’ of either the vaporising apparatus or the furnace becomes more and more acute the longer combustion is maintained.

This ‘choking’ is a fundamental defect which, so far, has not been overcome.

Everyone knows the result if the fireman neglects to remove the clinker from his fire, but it is much more difficult to remove the deposits from liquid fuel after vaporisation, than clinkers from the coal furnace.

There is only one satisfactory solution: that is, to burn these deposits, not in a mass after they have formed, even if that is possible, but before formation has taken place. To burn them requires a high temperature, and they must be distributed in the furnace with the lighter products while fierce combustion is taking place. Hence the object of atomisation.

Even with ‘paraffin’ lamp oil, which is one of the lighter products of petroleum, the deposit or residue from the vaporisation of the oil as the flame burns will be found firmly attached to the wick, which makes the ‘trimming’ or cutting off the top of the wick a daily necessity if a satisfactory result is desired.

The combustion of a certain quantity of oil will result in a certain percentage of deposit, according to quality, and it will be readily understood that if the burning of a gallon of refined petroleum per day will leave enough deposit to interfere with the efficiency of a lamp, the burning of a gallon unrefined petroleum per minute will soon choke a boiler furnace, unless a completely different system is adopted which entirely eliminates this defect.

Secondly, the admission and distribution of air was of hardly less importance. Though certain well-defined conditions as regards volume of air for a certain quantity of oil, and its method of admission, are now recognised as essential, early experimenters were entirely in the dark, and endeavoured to use the existing arrangements for coal-firing furnaces.

It is not clear who first recognised the importance of carrying out the first stages of combustion in a fierce draught. In all probability it was not observed till the steam jet introduced for atomising the oil created the draught, and even then it is doubtful if its value was fully realised, as many of the early burners neglected to provide for this advantage in their designs, evidently considering it of such little importance that individual users could make whatever arrangements they fancied best.

Even now there is more controversy over this subject of how air for combustion should be admitted to the furnace, and its method of control, than any other condition. No doubt it is largely due to the great variation in furnace designs, and the application of one or more burners.

Thirdly, there was the question of temperatures. Here again, without previous scientific analysis, the experimenter was completely in the dark.

No doubt he soon found oil would give a higher temperature than coal, but how indispensable it was to maintain a great heat, and take precautions to prevent its being lowered, from the admission of too much air or irregular flow of oil to the burner, was hardly considered.

Till the importance of atomisation, draught, and temperature was mastered, progress was very slow. From the historical point of view, the combustion of fuel oil does not appear to be of very ancient origin. Indeed, according to Butler, in his treatise on Oil Fuel, the earliest experimenter in this direction was a mechanic in

Russia, named Werner, who devised apparatus in the year 1861 for steam-raising purposes. The system was extremely crude, and apparently consisted of a series of grates over which the liquid trickled. No doubt it was accompanied by much smoke and deposit. Precisely how the fire was lighted up is not clear, but probably with solid fuel.

Shaw and Linton experimented in America on the same lines, but eventually patented a device in which the oil was vaporised and introduced into the furnace in the form of gas. Though this system was an improvement, its limitations prevented its general adoption.

However, in 1863, Brydges Adams introduced a spraying apparatus for astomising the oil for the purpose of applying liquid fuel to locomotives, and from this device modern oil-burning systems seem to have originated.

Though the advantage of atomising the oil had been proved, some experimenters still clung to vaporising systems, but their fundamental defects could not be overcome, and it is not surprising they scarcely emerged from the experimental stage. Richardson, in England, constructed what was known as an oozing furnace. Apparently the bottom of the fire-box was lined with slack lime, in which suitable ducts and spaces were left for the oil, which was consumed much after the manner of a wick lamp. Though experiments gave encouraging results, this method does not appear to have reached the commercial stage.

About 1864 Audouin, in France, brought out a drop furnace, in which the oil entered the fire-box at a comparatively high level, but here again the results do not appear to have been of such a successful nature as to be widely adopted. To the English inventors, Aydon, Wise, and Field, and a Russian named Spakovsky, undoubtedly belongs the honour of making one of the biggest steps forward in the art of oil burning.

Aydon employed superheated steam for his atomising agent, and the Russian a blast of hot air.

Selwyn, with Aydon, introduced a burner which was a further improvement, and won the approval of the Admiralty in a series of trials in a marine boiler, but the Lenz sprinkler appears to be one of the first, if not the first, oil burner to be used continuously on steamers. This device was a spray burner introduced in 1870 for the use of steamers on the Caspian Sea. Separate chambers were provided for the oil and atomising fluid, one above the other, and the burner was fixed in the fire-door. Regulation was carried out by means of semicircular slide valves in the burner head, and there is little doubt these were the cause of considerable trouble. Though the apparatus was extensively used, probably because no better type was available, it was not efficient in operation, and the complicated nature of the design made it costly to manufacture. Korting introduced a burner that met with some success. It was simple in construction, and neither the steam nor the oil orifice were mechanically controlled, but no provision was made for admitting air with the jet, as in the Aydon and Selwyn burner of an earlier period, which it otherwise closely resembles. Not unnaturally, early investigators devoted much time to liquid-fuel burners for locomotives, as in oil-producing countries it was obviously absurd to have to import coal for steam-raising purposes.

Professor Urquhart seems to have been one of the first to introduce a satisfactory appliance for this purpose. His burner closely resembled a steam injector. The coned nozzle could be inserted in a sleeve expanded in the fire-box plate in the front of the locomotive. As the nozzle was considerably smaller than the internal diameter of the sleeve, an air space was provided through which a fierce draught was induced by the action of the steam jet. This was of great assistance to good combustion.

From this date, about 1885, many burners of similar construction have been placed on the market, but it is doubtful if any great improvement in the design has taken place. However, burners suitable for culinary purposes appear to have been entirely neglected.

At the present day there are two distinct systems of atomising oil, the pressure jet system and the atomising fluid system ; all others, such as the oozing furnaces and drop furnaces mentioned above, having been abandoned, probably because of the impossibility of obtaining complete combustion by such means. For efficient oil firing it is exceedingly difficult to lay down definite instructions. It is no doubt true that in many cases the burner itself is of secondary importance, while the furnace setting and air control merit first attention.

A satisfactory arrangement in one case may be unsatisfactory in another, and often enough the real cause of poor combustion is undetected. It is one of those problems which can only be solved by careful observation, and it is not surprising early investigators often pursued false clues which were eventually abandoned.

ATOMISING SYSTEMS.

The pressure jet system effects atomisation of the oil by forcing it through a small hole which diffuses the oil in a spray. The oil must be previously heated, and, maintained at a high temperature, passed through fine filters ; and forced draught from fans, to assist combustion, is also required to obtain the best results. For large powers it is efficient, if complicated, and its advantages over coal firing, for marine purposes, are so great that it has been widely adopted.

The atomising fluid system effects atomisation of the oil by means of a jet of steam or air injected into the furnace, in such a manner as to intermingle with the oil and cause diffusion. With suitable arrangements, it will induce sufficient draught for combustion. Fine filters are not required ; but the best results are obtained by preheating the oil. It is exceedingly simple, but in large plants the power absorbed by the atomising fluid amounts to a considerable figure.

The atomising fluid system of burning oil may again be divided into two classes : those of the injector type, which induce the oil to enter the furnace at a high velocity with the steam or air, and those of the spray type, in which the atomising fluid leaves the orifice before it comes in contact with the oil, which it carries into the furnace.

Now, as a matter of fact, there is nothing simpler than to construct a liquid fuel burner for steam-raising purposes. Take a short length of wrought-iron pipe, draw out the end into a cone. Place a similar coned pipe of smaller dimensions inside the larger pipe, so that the orifice consists of a central passage for the steam and a circular slit for the oil. If you are mechanic enough to design arrangements for the regulation of the oil and steam, you have all the essential features of the fluid atomiser burner. It must, however, be properly applied to the furnace to give reasonably efficient results. But when it comes to applying such a crude apparatus to a kitchen range, it is at once apparent that what is good enough for a steam boiler or large furnace, is out of the question for culinary purposes. There is no necessity to describe at length the limitations of existing burners, or analyse the technical reasons why they cannot be applied to the ordinary range ;

but some of the conditions that should be complied with for successful daily working are given below. They are:

A burner

1. That will not choke;
2. That will produce a flame of a few inches in length or a couple of feet;
3. That will heat up the range from cold in the same or less time than when using solid fuel;
4. That is perfectly safe and cleanly to operate;
5. That can be cleaned inside without removal or the use of spanners and tools;
6. That, together with the necessary fittings, does not restrict access to the front of the range or interfere with any cooking operations;
7. That is of such simple construction that an illiterate scullery hand can look after it;
8. That is absolutely reliable;
9. That gives a clear fire and smokeless combustion;
10. That can be applied to the ordinary closed range without structural alterations or complicated accessories.

To design a burner on the pressure jet system to comply with the above conditions, the orifice for the oil would be of such minute dimensions that it would be liable to choke, even if it was found practicable to install the necessary pumps, filters, and heaters in a domestic kitchen.

To design a burner on the injector type, the same danger of choking exists, even if this fault did not occur from constant relighting of the burner.

There remains the spray type of burner, characterised as having

1. A full-way orifice for the oil that cannot be obstructed

by foreign matter, or subject to carbonisation that cannot be easily removed;

2. A gravitation feed, and a nozzle so disposed that the oil is not precipitated in drops, but ensures the constant uniform flow of the smallest possible stream;
3. A minute orifice for the atomising fluid, so disposed that it will not choke, but ensures the fluid meets the oil with the maximum velocity and pressure;
4. A casing that induces draught at the point of combustion, thus ensuring the complete mixture of the combustible gases;
5. A regulating device for the oil and the atomising fluid, which is capable of accurate and independent adjustment.

II

APPLICATION OF BURNERS TO KITCHEN RANGES

The Scarab Burner.

Figs. 1 and 2 illustrate the Scarab burner, which complies with the conditions set out in the last chapter, and can be applied to the ordinary kitchen range, as shown hereafter. Fig. 1 shows a side elevation, and Fig. 2 the end view facing the nozzle.

During the war, when coal in Egypt was £14 a ton, and fuel oil £6, 5s., it was clear that if a fuel-oil burner could be applied to the kitchen range, an enormous saving in cost of fuel and oversea transport would result. Many engineers devoted much time and money to the problem, without success. It was a question of not only the burner, but its application to the kitchen range in such a manner as to be acceptable to the cooking staff. As is often the case, the secret of an invention lies in its *application*, and the *successful application* of an invention lies in making

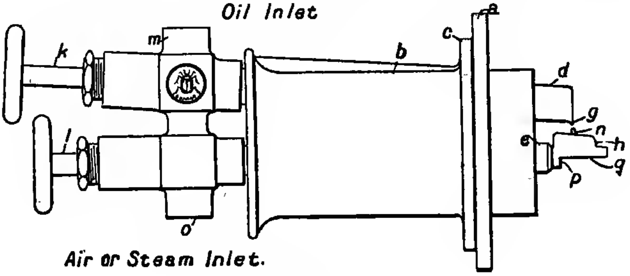


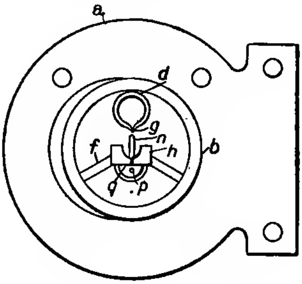
FIG. 1.

a *minute study of the conditions* under which it will have to work, and seizing the essentials.

The Scarab burner was designed to burn the exceptionally heavy residues from the Anglo-Egyptian Red Sea Oil-Fields, and, as far as the writer is aware, is the first fuel-oil burner which has been in regular daily use month after month for cooking purposes in an ordinary kitchen range.

Briefly, the burner consists of a cast-iron plate or frame (*a*) to which is hinged a hollow cylindrical casing (*b*) provided with a flange (*c*). Through this casing passes the oil-pipe (*d*) and the compressed air-pipe (*e*), supported by the web (*f*). These pipes terminate in a lip (*g*), and a nozzle (*h*) at one end of the casing (*b*), and in a header common to both pipes at the other.

In this header is a regulating valve (*k*) for the oil, and a similar valve (*l*) for the air. The oil enters the header from the upper side at (*m*), as shown, flows down the pipe (*d*) till it creeps from the lip (*g*) on to the pin (*n*) in the nozzle (*h*), and clings to the extreme end. The compressed air enters the bottom of the header at (*o*), as shown, and issues from the orifice (*p*) beneath the nozzle, impinging on the flat under-surface (*q*), which spreads the air jet in a fine film, and carries the oil clinging to the extremity of the nozzle into the furnace.



End View.
FIG. 2.

With the ignition of the spray a fierce draught is induced through the casing (*b*), atomisation is complete, and a steady luminous flame of dazzling brilliance is maintained as long as the oil and the compressed air continue to flow.

It will be observed the oil-pipe has a full way to the lip, therefore it cannot choke, and as the valve spindle can be withdrawn, a clear view can be obtained throughout its length while fixed in place. The air orifice is so situated beneath the nozzle that it cannot be choked by the oil, and the induced draught through the casing directs the air on to the point of fierce combustion where it is most required, and becomes heated before distribution in the furnace.

It will be observed this burner is of exceedingly simple construction, and though the disposition of the various parts which make up the apparatus are not at first apparent to the eye, a brief experience in daily use will disclose the merits of the design.

As fuel oil contains a greater heating power than coal, a larger volume of air is required for combustion, but not an excess volume as the furnace is cooled, and for good combustion a high temperature must be maintained. High temperatures are extremely sensitive and depend upon a uniform supply of fuel, atomising fluid, and air for combustion, but the air for combustion must be introduced into the furnace in the form of a fierce draught that will immediately intermingle with the pulverised fuel before coming in contact with the sides of the furnace.

The dimensions of the flame depend upon the volume of the atomising fluid ; but there is a ratio between this volume and the fuel which must be maintained for combustion purposes. If the supply of fuel is in excess of what is required, it will not be sufficiently pulverised. If the volume of atomising fluid is too great, the flame will be blown out, and the oil deposited on the walls of the furnace.

To maintain a small flame, a small volume of atomising

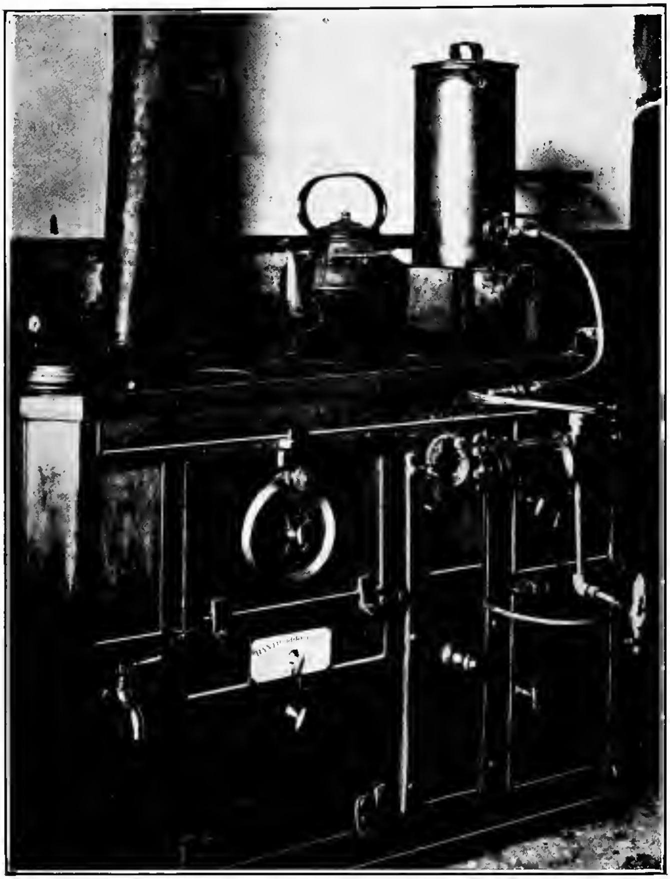


Fig. 3

Scarab Burner applied to Kitchen Range

fluid only is required ; but it must have velocity. To reduce the volume from a large orifice by a regulating valve, reduces the velocity, therefore a small orifice must be provided. The greater the pressure and velocity at the point of contact between the oil and the atomising fluid, the more efficiently is the oil pulverised, and the fiercer the induced draught. In other words, if one requires a small flame and good combustion, the essentials are :—

1. The free flow of the fuel in the finest possible stream.
2. Velocity and area, without volume, of the atomising fluid.

Now a minute jet of air with a high velocity has no magnitude or area, but the fuel is of a clinging, viscous nature, and for the air to effectively 'pick up' the fuel, the jet must be 'flattened' or increased in width before it will distribute the oil in the furnace. Hence the disposition of the air orifice so that the jet expands by first impinging on the flat under-surface of the nozzle. By this means the maximum use is made of a minimum volume, and velocity is maintained at low pressure.

BURNER APPLIED TO KITCHEN RANGE.

Fig. 3 shows the application of this burner to a small kitchen range in daily use. The burner is shown open for inspection.

The object of the hinge is at once apparent, and the flexible metallic pipes for the oil and air connections enable the burner to be opened without unscrewing nuts or couplings, as it is of great importance in domestic use that no oil should drop on the floor, or that spanners and tools should be required for inspection or cleaning purposes. The frame of the burner is screwed to the front of the range, and a hasp bolted to the range presses the flange closely in position when the burner is firing.

In this case the range is of the French pattern, with a closed front, and when the ash-pit door, which can be seen below the burner, is shut down, the air supply has to pass through the burner casing. In such a small range as shown in this photograph, no additional air supply is required. In ranges that have open front bars, the burner is fixed to an iron plate, which forms the front of the range. No alteration has been made in the level of the fire, so solid fuel may be burnt with the oil, or as an alternative, if required.

The oil reservoir, which supplies the burner with fuel, can be seen on a stand, under which a lamp or Primus stove may be set for initial heating purposes ; but when the range is hot, the lamp can be dispensed with, as the radiation is quite sufficient to heat the fuel oil to the desired temperature.

The air-pipe can be seen fixed between the oven doors, and the supply in this case is taken from the street mains, at 20 lbs. square inch pressure, which supply the pneumatic ejectors for draining the city of Cairo. The range is one of those in use in the Kasr-el-Eini Government Hospital, Cairo, but is not used for heavy cooking.

The quantity of oil such a range will consume depends how often it is lighted up, and the work required ; but for simply keeping the water at boiling-point, or boiling kettles of water, the consumption during the first night it was used worked out at less than 2·2 lbs. of fuel oil per hour. It is interesting to note that on this first occasion the burner was lighted up at 10 P.M., and the responsible attendant went to bed as usual. At 6 A.M. the burner was working as he left it, the hospital orderlies having made use of the range during the night precisely as if solid fuel had been in use, with the difference that no stoking or replenishing of the fire was required.

To start the burner from cold, fuel oil is poured into the reservoir. The lamp is lighted, and in five or ten minutes the vessel has become hot to the touch. Kindling material, such as straw and small sticks, are then placed in the fire-grate and lighted. The air is turned on, then the oil. In a minute or so the pulverised oil ignites, a fierce draught is induced through the casing, and if full power is employed the top of the range will become cherry red in about fifteen minutes, if vessels of water are not placed thereon.

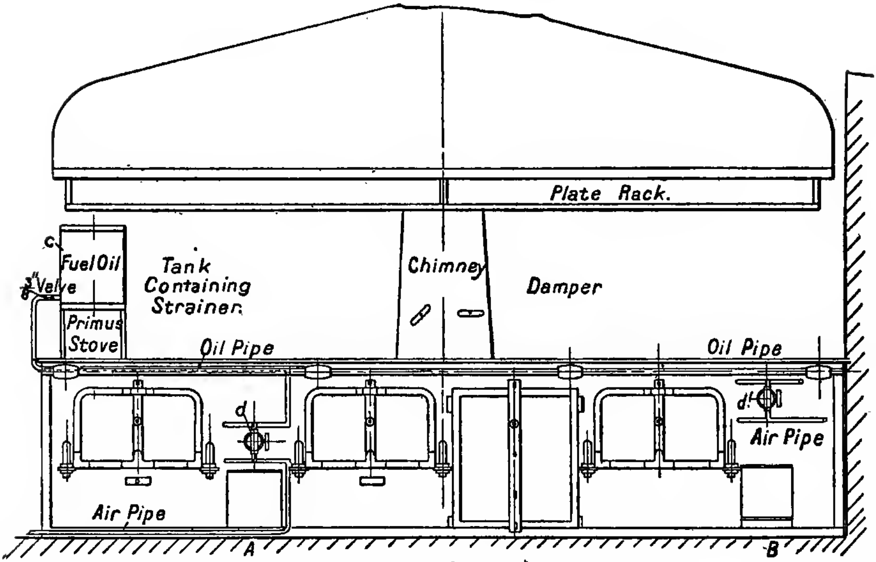
With the exception of cutting a small round hole in the front of the range, and placing extra fire-bricks in the grate, no alterations to the range were carried out—the existing flues, dampers, and chimney remaining precisely as they were designed for solid fuel. It must be remembered that the average type of kitchen range gives an excellent draught, which is of great value in burning oil fuel.

Firing Large Double-Furnace Kitchen Range.

Figs. 4-6 show how the Scarab oil-burning system is applied to a large kitchen range at the Turf Club, Cairo.

Fig. 4 is a front elevation. Fig. 5 is an end elevation, showing a section through the right-hand fire-grate *B*, in which solid fuel can also be burnt as an alternative. Fig. 6 is a plan showing how the range is situated in the corner of the kitchen, and the position of the oil reservoirs.

The oil reservoirs *c*, c^1, hold about three gallons each, and are arranged at such a height that a Primus stove can be placed beneath them for initial heating purposes, and so that the oil will flow by gravitation to the burners *d*, d^1. Owing to the awkward situation of this range, reservoir *c* has a considerable length of oil-pipe to the burner, and on cold mornings it is necessary to warm the pipe with the Primus stove before starting, if the

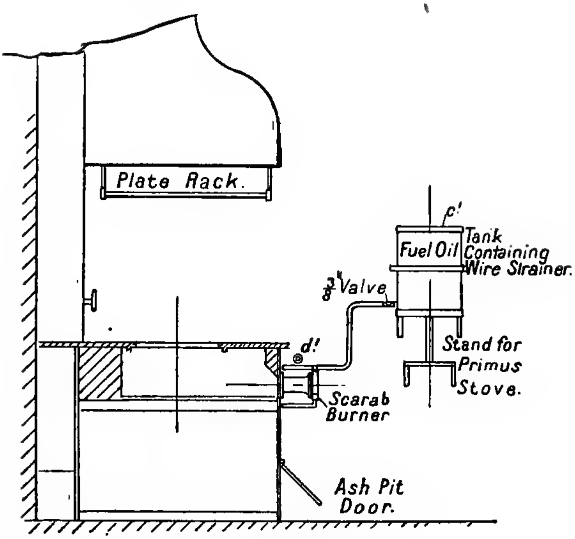


Front Elevation of Kitchen Range.

FIG. 4.

cheapest quality of fuel oil is to be used. On the other hand, c^1 is placed on a wall bracket and a short oil-pipe connection is possible; but being away from the top of the range, the oil is not kept at a high enough temperature to get the best efficiency when the lamp is removed. The reservoirs, of course, cannot be placed in any situation that would interfere with the cooking, but it is desirable to place them as close to the burners as possible.

Though it would appear from the plan ample space exists above the range, it must be borne in mind when



Cross Section B.

Fig. 5.

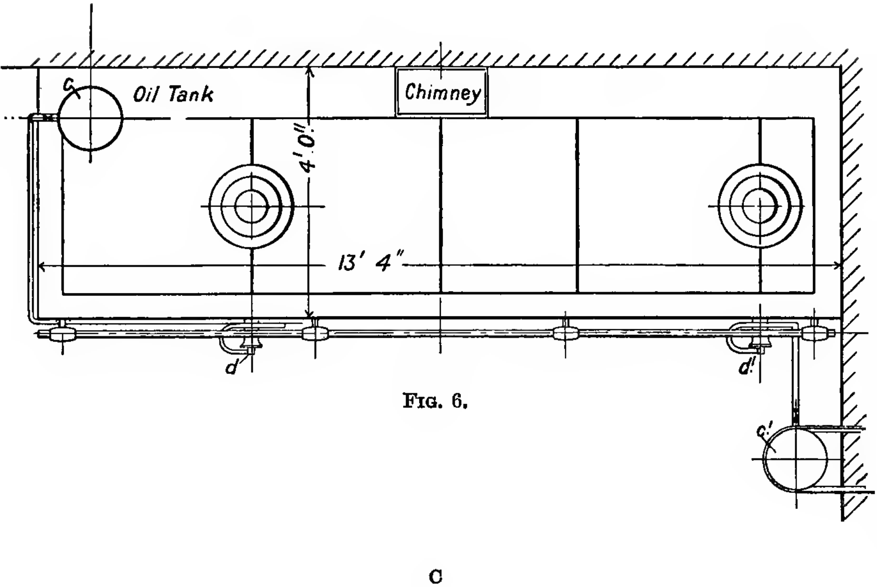


Fig. 6.

such a kitchen provides for 230 persons per day, available space is completely covered with cooking utensils at busy periods of cooking operations. From the reservoir *c* the oil-pipe can be traced round the corner of the range, passing behind the guard rail till it bends down to the flexible connection attached to burner *d*. The air-pipe is coupled to the burner by a smaller connection, and runs round the corner of the range at floor level, till it meets a lead service pipe, which draws its supply of air from the cast-iron street main, that provides compressed air for operating the pneumatic ejectors which drain the city. The average pressure is 20 lbs. square inch, and the volume required for the burner depends on the fierceness of the fire it is desired to maintain.

CONSUMPTION AND COST OF FUEL.

The consumption of oil varies, but taking an ordinary day's work a few weeks after the burners had been installed, it was found, without any attempt at economy, that 48 kilos (105 lbs.) of fuel oil will do the work of 107 kilos (235 lbs.) of coal.

The following extract from the yearly report of the Club is significant :—

'It is of interest to note that considerable economy has been effected on the fuel, by the installation, in July last, of Mazout (fuel oil) burners in the kitchen. The full economy will be realised in the current year, when these burners will have been working for the whole twelve months.

'CAIRO, 17*th March* 1919.'

On inquiries being made as to the amount saved by the installation of Scarab burners, the Secretary kindly supplied the following figures :—

Fuel.

March 22, 1919.

January to June 1918	£E.526.25	(Coal.)
July to December 1918	£E.199.16	(Oil Fuel.)

'We have not used coal since end of June.' (1918.)

From these figures it is not unreasonable to make the following deduction :—

Result of installing Scarab burners at Turf Club, Cairo :

January to June, 1918	£E. 526.25	
Cost per year	£E. 1052.50	(Coal.)
July to December, 1918	£E. 199.15	
Cost per year	£E. 398.32	(Oil Fuel.)

Coal per year	£E. 1052.50
Oil fuel per year	£398.32
Saving per year	£E. 654.18

= six hundred and fifty-four pounds and eighteen piastres.

The Egyptian pound is worth 6d. more than the English pound, but for purposes of comparison the above figures may be taken as they stand. It is true that the prices of coal and oil were inflated during the war ; but if the Club had purchased coal from July to December 1918, they would have had to pay more than in the previous six months, and the difference would have been even larger than shown. An inquiry made at the Club, dated 15th August 1918, elicited the following reply from the chief steward :—

'TURF CLUB, CAIRO.

'SIR,—We are using about 24 tins of oil a week, which cost	£E. 4.92
and a little cake, cost	1.00
'Amount per week is	£E. 5.92

‘The coal we used to burn was about three-quarters of a ton per week, which cost	£E. 12.75
Wood about	1.00
	£E. 13.75

‘Yours faithfully,
‘E. G. M. (*Steward*).’

There has been no instance when these burners have ever failed, and the daily meals have been provided with regularity. In this case it is all the more remarkable, as the burners are operated by an illiterate scullery hand, with absolutely no knowledge of the art of oil burning whatever. That it is possible to make a reduction in the consumption of oil, there is no question ; but in a large kitchen, experimenters are not welcomed, and the first installation of oil fuel as a substitute for coal in culinary operations is no doubt due to necessity.

The reliability of these burners, and the uniform heat it is possible to maintain, is remarkable. There is no failure of the fire when once started. The cook fills his oven, arranges his stew-pans, sets the burners, and literally ‘goes to sleep,’ as the writer can testify, on unexpectedly visiting the Turf Club kitchen one afternoon about 3.30 P.M.

Nearly all the cooking is done over the left-hand burner *d*. That is to say, this one burner is responsible for cooking for nearly two hundred people a day. There is no doubt it is more economical in fuel consumption to run one fire-grate at its maximum capacity than to run two at half-power.

There is, however, a limit to the quantity of oil a certain sized burner will consume, and a limit to the combustion in a given area. Only a certain quantity of oil can be burned in a grate of a certain size. If too much oil is fed into the furnace, smoke will result, carbon will form, and, if this is done in the early stages of lighting up, it will put the fire out.

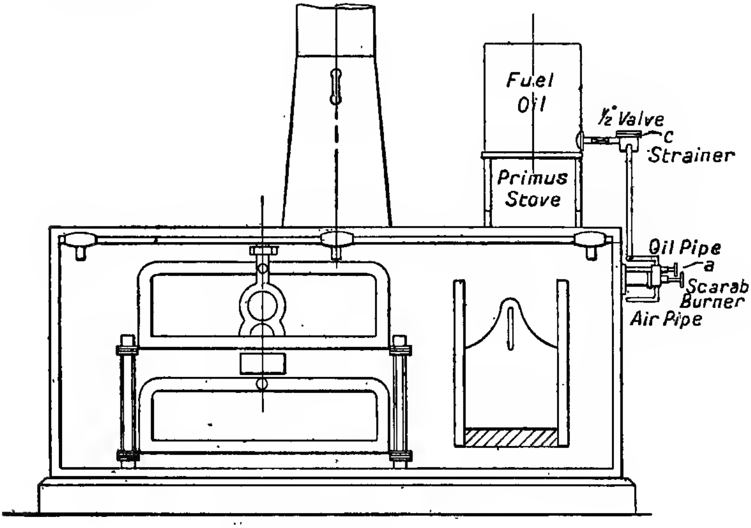
As already mentioned, the practice in the kitchen is invariably to force the fire, and this can be done with oil more economically than coal, as the higher the temperature is kept, the more efficiently combustion takes place. When once the fire is well under way, there is no reason why any smoke should be produced, and a good plan is to set up a couple of mirrors, so that the cook can see the reflection of the top of his chimney, and be able to force his fire to the maximum, but keep within the limits of combustion for which his range is capable. With no smoke there is no soot and no deposit, the high temperature of the furnace completely consuming the products of combustion.

Firing Large Single-Furnace Kitchen Range.

Figs. 7-9 show a large single fire-grate kitchen range at the Kasr-el-Eini Government Hospital, Cairo, to which the Scarab oil-firing system has been applied. Fig. 7 shows the front elevation, Fig. 8 the end elevation, and Fig. 9 the plan. In each view the necessary accessories for burning the oil in place of coal are clearly shown.

The position of this range permitted of a very simple and effective arrangement. It will be observed the burner *a* is fixed in the end of the range, and not in front, and the oil reservoir *b* is placed on a bracket, fixed to the wall over the back of the range. As far as cooking operations are concerned, this leaves the front and top of the range perfectly free. Coal and coke may be burnt at the same time, or as an alternative, at a moment's notice.

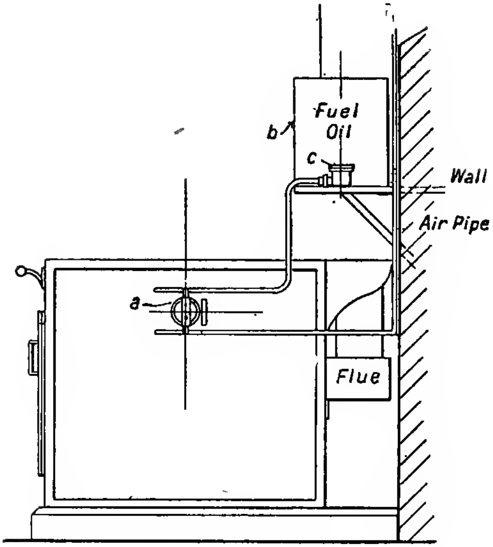
The bracket on which the reservoir stands allows of a Primus stove being placed beneath it for heating the oil to light up the fire. The oil reservoir holds about 2½ gallons, and in place of an interior wire cage for straining the oil, a small strainer box *c* is provided on the outlet pipe.



Elevation.
FIG. 7.

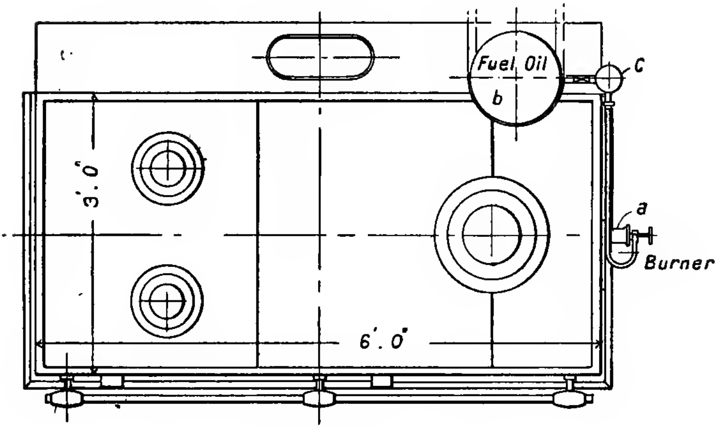
The whole arrangement is, without doubt, one of the most convenient and efficient. No attachment is made to the front of the range, the oil-pipe is short, the fuel is kept at a high temperature by the heat from the range, and the flame is evenly distributed as it passes over the oven flue.

As far as the writer is aware, this was the first example of an ordinary kitchen range in daily use for heavy cooking being fired with oil fuel and an atomiser burner, and there is no question the results surpassed the most sanguine expectations.



End Elevation.

FIG. 8.



Plan.

Oil Firing Single Furnace Kitchen Range.

FIG. 9.

As no official trial has taken place to ascertain precisely the minimum amount of oil that it takes to cook a given quantity of food, the best efficiencies are a matter of conjecture, but from May 1918 to April 1919, the official figure, supplied by the director of the hospital, was 1500 kilos (3300 lbs.) of fuel oil, equals 3000 kilos (6600 lbs.) of coal, these figures representing the average quantity consumed per month. Weight for weight, this is a saving of 50 per cent.; but as the market price of coal was £14 per ton, and fuel oil £6, 5s. per ton, it will be readily understood that the saving in cost of fuel has been enormous. Some weeks after this installation had been at work it was found that by taking the average over several days, 38 kilos (83 lbs.) of fuel oil was equal to 80 kilos (176 lbs.) of coal. The monthly figures given above, of course, include all wastage, which, owing to the carelessness of native labour, often amounts to a considerable figure. For instance, cases have been known where a native cook has attempted to start the fire with cold oil, with the result that quantities of the liquid fall through the grate into the ash-pit pan, which is always provided for such contingencies. The air supply is taken from the Cairo main drainage system of compressed air mains.

As previously remarked, in initiating a new system, or applying a new device to an existing apparatus on which numbers of people depend each day in the performance of their routine work, it is not so much the device itself, but making its application acceptable to those who use it, that must be considered.

In the case of a domestic necessity such as the kitchen range on which the daily meals are prepared, the slightest hitch or interference with custom is resented, and faults which have nothing to do with the invention are nevertheless at once credited to the new device. Thus, if the oil reservoir is allowed to run dry, and the fire goes out, the attendant will blame the burner before finding the cause. In the same way, if a pipe is injured, and the supply of air interfered with, he blames the burner, without a thought of looking elsewhere. Science does not form part of the education of a kitchen staff, and economy is a foreign word, which conveys no meaning. Why should it ? It is not reasonable to expect such abilities in this class of labour. We must accept things as they are, and first devise apparatus that can be operated by those who will use it, regardless of its scientific and technical perfections. The 'technical touch' is entirely absent in the average kitchen. The manipulation of a water-tap is usually the beginning and end of the kitchen man's knowledge of practical mechanics, and the kitchen poker is the only tool he understands how to use with effect.

He does not comprehend what he cannot see. If a gas flame or a wick lamp gives insufficient light, he may turn it up, and the desired result is attained, but if an oil-fired furnace is giving insufficient heat, he is unable to understand that by restricting the flow of cold air, he is often able to increase the heat of his furnace without having to increase the flow of the oil. In the same way, if smoke is produced, that does not concern him ; it is not his trouble—he does not pay for the fuel. His coal fire used to smoke, so why should not oil ?

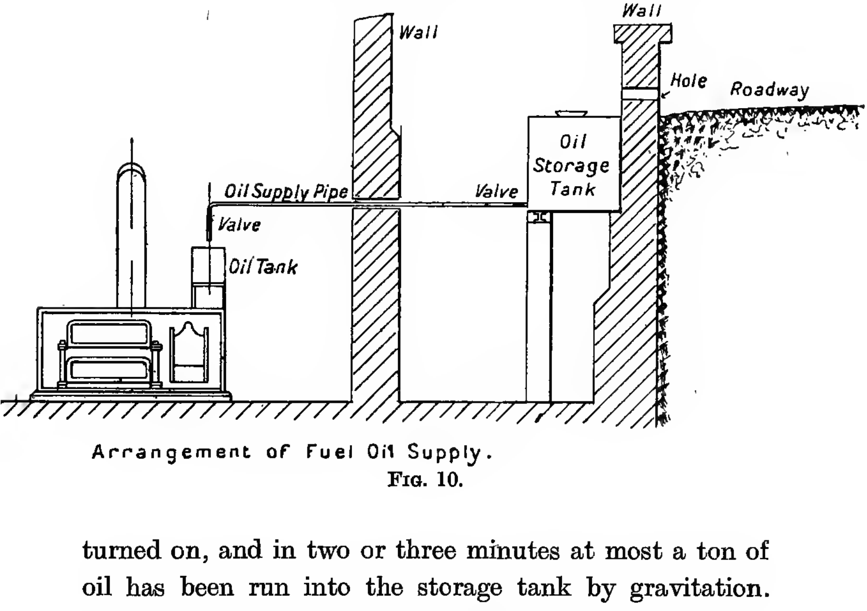
If it was necessary to keep the top of the range cherry red to get the day's work done with coal fuel, it will certainly be necessary to keep it red-hot with oil fuel. Again, he soon finds that it is much easier to make it red-hot and keep it red-hot with oil fuel than with coal, and at certain times of the day, instead of having to stoke the fire and shovel on coal, he simply opens the oil regulator and takes it easy for an hour. Lectures on care and efficiency are mere wasted words on a tired undercook. The work for which he is being paid is being done, and he feels justified in taking whatever relaxation in his labour he can get, regardless of any extra expense to his employers.

It is, of course, possible to construct the regulator so that it will only open to permit of a certain flow of oil, but this has not been found satisfactory in practice. If this is done, it takes longer to start the fire, as in starting up early in the morning from cold, the oil is invariably at too low a temperature to run freely, and it must be possible to open the regulator to a greater extent than is required when the oil has become heated. Again, the advantage of being able to completely withdraw the regulator spindle for inspection is very great. This refers to the use of the cheapest qualities of fuel oil, but the cheapest qualities are just those that the proprietor wants to burn, as he naturally and rightly fails to see why he should go to greater expense to save the scullery hand from getting up a little sooner in the morning and exercising a little more care with his fire. But human nature is much the same all the world over, and the underhands see no necessity to study domestic economy, or commence their daily duties before it is absolutely necessary to do so. If we do away with manual labour, a little care and intelligence must take its place.

METHOD OF OIL SUPPLY TO KITCHEN RANGE.

Fig. 10, page 43, is a diagram showing how a kitchen range fixed in a basement (which is not at all an unusual position for a kitchen to be in) is supplied with oil, without handling the fluid in tins or buckets. The arrangement is a great advantage, as careless servants are apt to spill the oil in filling the feeding reservoirs, and its viscous nature makes it unpleasant to remove.

The diagram is taken from the existing level at the Turf Club, Cairo, already described. The oil company deliver the oil in a horse-drawn tank, the outlet to which is about three feet above the surface of the road. A three-inch pipe, with a funnel at one end, is thrust through the hole shown in the wall. The oil-cart tap is turned on, and in two or three minutes at most a ton of oil has been run into the storage tank by gravitation. This equals about three weeks' supply.



Arrangement of Fuel Oil Supply.
FIG. 10.

From the storage tank the oil will run by gravitation to the feeding reservoir above the kitchen range, the cook merely having to turn the oil-tap when the reservoir is empty.

From unloading the oil cart to 'putting the oil on the fire' no manual labour whatever is required compared to unloading a ton of coal, storing it in the coal-cellar, fetching it to the kitchen scuttle, and, finally, shovelling it on to the fire. In comparing the costs of oil and coal firing, such economies in labour and time must not be overlooked.

FIRING LARGE CENTRAL DOWN-DRAUGHT KITCHEN RANGE.

Figs. 11-13, page 45, illustrates the method of applying the Scarab oil-burning system to one of the large central down-draught kitchen ranges at the Grand Continental Hotel, Cairo.

Fig. 11 shows a section through the kitchen with a front elevation of the range. Fig. 12 is the plan looking on the top of the range, and Fig. 13 an end elevation.

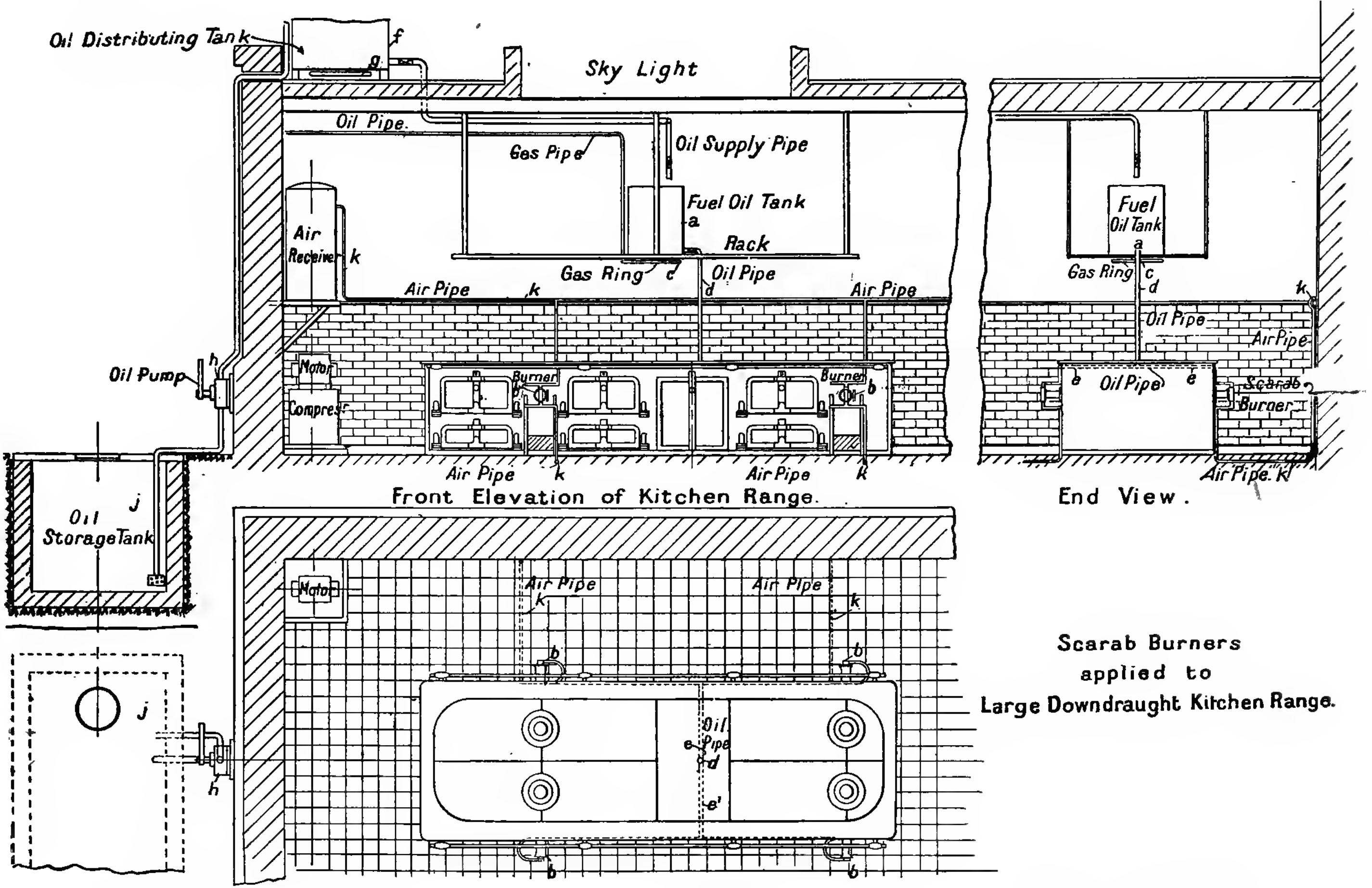
The installation is a large one, comprising in all some twenty-two burners, the majority of which are constantly at work. In a large hotel of this description, which is capable of providing for eight hundred people, extensive firing is required, not only for the kitchen range, but for the hot-water system and dust destructors.

The first range was successfully oil-fired at the end of August 1918, and so satisfied were the management that they decided to proceed with the complete substitution of fuel oil for coal throughout their premises, and there has been no instance of failure, to date.

Owing to the war, motors and air-compressors were quite unobtainable, and this hotel, like the Turf Club, and hospital, draws its supply at present from the Cairo main drainage system. Methods of air supply will be fully dealt with later.

It will be observed this type of range stands away from any wall, thus providing the maximum area for cooking and free access from all directions. It has four furnaces, to each of which a Scarab burner *b* has been applied.

The reservoir *a* for supplying the burners *b* with oil



Scarab Burners
applied to
Large Downdraught Kitchen Range.

FIG. 11.—FRONT ELEVATION.

FIG. 12.—PLAN.

FIG. 13.—END ELEVATION.

is placed on the rack above the range, and a gas ring *c* takes the place of a Primus stove for heating the oil when cold. A single pipe *d* is taken from this reservoir to the top of the range, and underneath the plate top it branches (e, e^1) to right and left, to supply the four burners *b*. By this means the oil is heated on its way to the burners, and no obstruction, with the exception of the single vertical pipe *d*, interferes with the cooking operations.

The reservoir *a* is fed from a distributing tank *f* placed on the roof of the kitchen, which also supplies oil to the other ranges. A gas ring *g* is also provided for warming the oil; but this would only be required in very cold weather. This distributing tank is in turn supplied with a hand-pump *h*, which raises the oil from the storage tank *j* placed beneath ground level, outside the building. The storage tank is supplied from horse-drawn iron tank carts. From this it will be seen there is no handling of the oil whatever; and in a large installation of this description a small power pump for raising the oil would be a further economy.

Compared to the expense and manual labour involved in transporting coal, and keeping a dozen kitchen furnaces up to red heat for twelve hours a day, there is none.

The air-pipes *k* supplying the burners pass under the floor so as to form no obstruction, and run round the kitchen wall to the air-receiver. With a supply from the city mains, however, no receiver is necessary.

In this case it was found advisable to bring all the existing chimneys into one shaft, as it not only improved the draught, but any smoke is carried away far above the house-tops. With twenty-two burners firing into a single chimney, it is difficult at times to avoid some smoke, as if half a dozen burners are being forced at once, the one that is being fed slightly in excess of its capacity is difficult to detect. However, with some slight furnace modifications, there is little doubt that kitchen-range chimneys can be made as smokeless as power-house chimney shafts.

III

AIR SUPPLY AND OIL CONSUMPTION

FIRING SMALL KITCHEN RANGE.

Figs. 14-16, pages 49-51, show a small oil-fired kitchen range at the Kasr-el-Eini Hospital, Cairo, in the same kitchen as the range already described. It has been in daily use since August 1918, and the supply of air is drawn from the main drainage system.

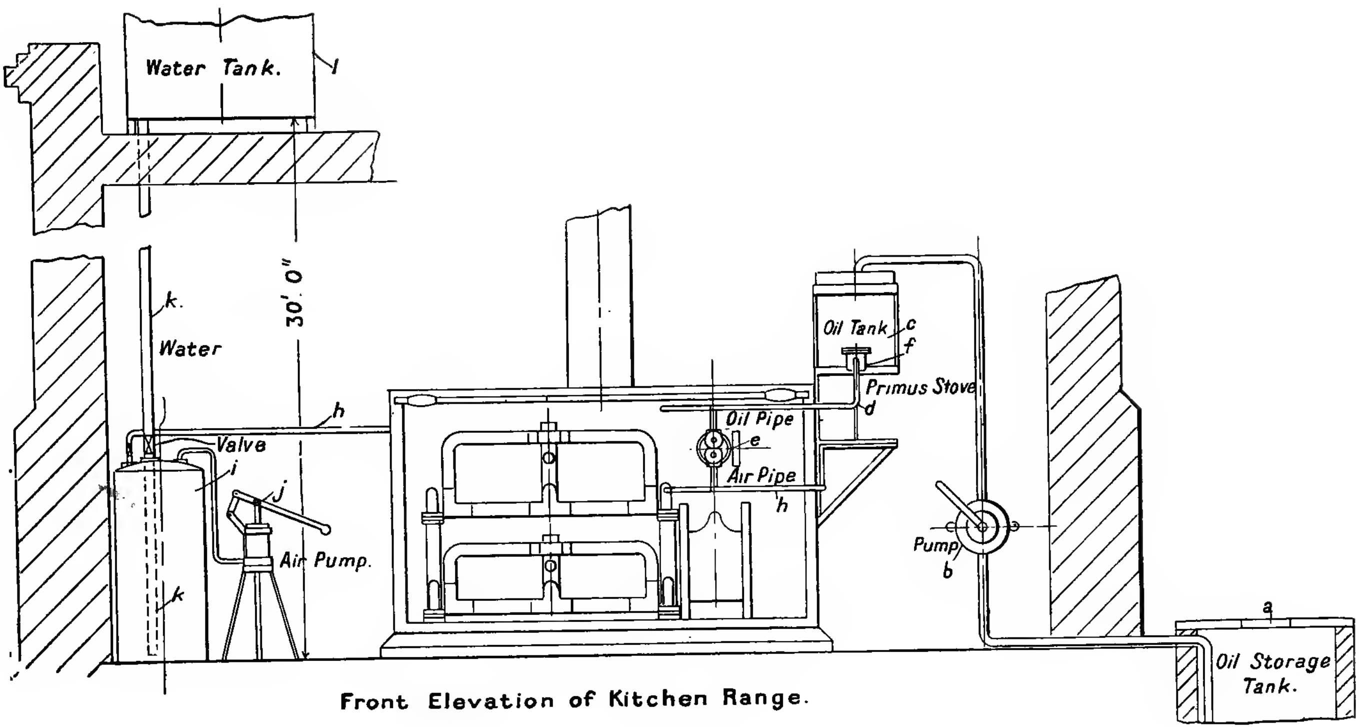
Fig. 14 is a front elevation, showing how an independent air supply may be arranged.

Fig. 15 is an end view, showing the oil reservoir on a bracket attached to the range.

Fig. 16 is a plan of the installation.

The storage reservoir *a* is supplied with fuel oil by the oil company's tank cart. By means of the hand-pump *b* the oil is delivered directly into the reservoir *c*. Before passing down the pipe *d* to the burner *e*, the oil passes the strainer *f*, which can be shut off for cleaning purposes by the valve *g*. The air-pipe *h* is taken round the back of the range to the air-receiver *i*, which is filled with air from the hand-pump *j*. From the bottom of the receiver *i* a pipe *k* is connected to a water-tank *l* at any height above the range, according to the air pressure desired.

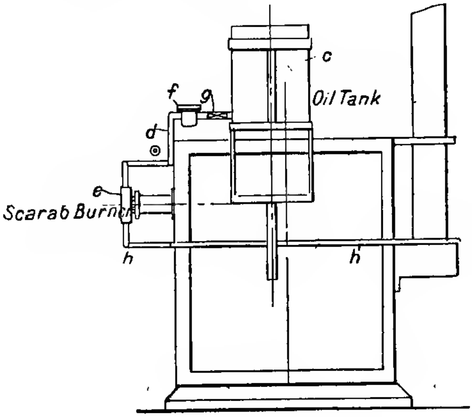
The water-tank *l* is of such a capacity that its contents will fill seven-eighths of the air-receiver. When at rest the air-receiver *i* is full of water to within one-eighth of its capacity. As the air-pump *j* is worked, the water in the receiver *i* is forced up the pipe *k* into the tank *l*. If the burner *c* is working, the air will be drawn off under a



Front Elevation of Kitchen Range.

FIG. 14.

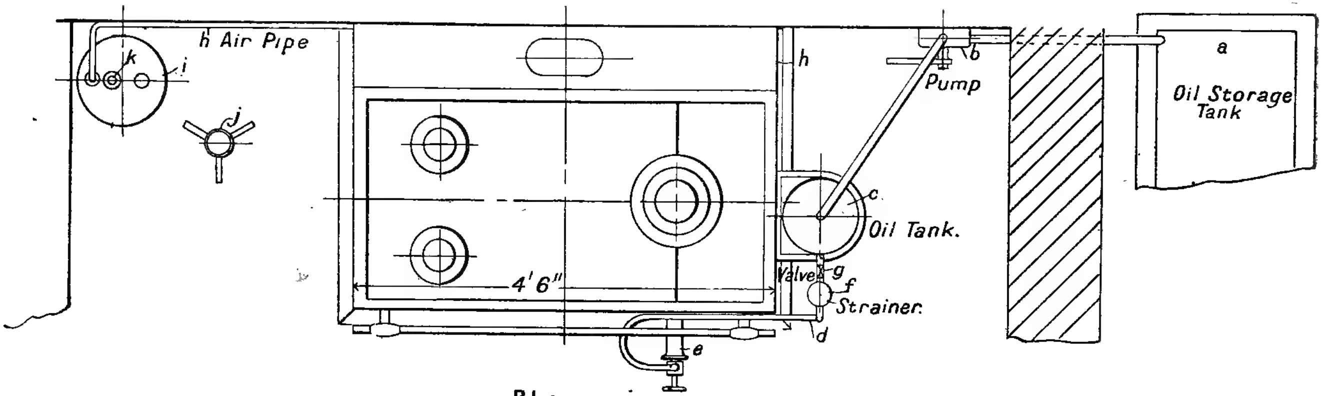
steady pressure as the water in the pipe *k* will rise and fall with each stroke of the air-pump, thus compensating for the uneven discharge of the pump, and ensuring a steady flow of air to the burners. If pumping is continued when the burner is not working, the air simply passes out through the water in the tank.



End View.

FIG. 15.

An apparatus of this description will easily work a single burner, but it must not be supposed pumping can cease for any length of time, unless the receiver *i* is a large one. There is a certain amount of storage, as it is obvious as soon as pumping stops, when the burner is working, the air will continue to flow from the receiver at the same pressure, till it has been entirely displaced by the water gravitating from the tank *l*. The merit of this system is that, being exceedingly simple, there is nothing to go wrong and get out of order. If storage is desired, a receiver with a reducing valve should be employed, when from a pressure of 30 lbs. square inch or 40 lbs. square inch the burner will work from one to two hours at 5 lbs. the square inch.


h Air Pipe
k
i
j
h
b
Pump
a
Oil Storage Tank
c
Oil Tank.
Valve
g
f
Strainer.
d
e
4′ 6″

Plan.

FIG 16.

In countries where labour is cheap, and the range is wanted for a few hours a day only, hand power will be sufficient. As previously described, for lighting-up purposes, a Primus stove is placed on the bracket beneath the oil reservoir *c* till the oil is hot, when kindling material is lighted in the fire-grate. The oil and air valves are then opened, and in a few minutes the pulverised oil ignites.

AIR SUPPLY.

From the preceding descriptions of oil firing kitchen ranges, it is clear a supply of compressed air is necessary for atomising the oil.

Though the Scarab burner will work well under certain conditions, with a pressure as low as 3 lbs. square inch, higher pressures are recommended, such as 20 lbs. to square inch, or 30 lbs. and 40 lbs. for combustion purposes. Hot air is more efficient, but the extra economy due to this cause in so small an installation as a kitchen range is not at present worth considering.

Methods of supplying the necessary air will suggest themselves to many readers, and it is only proposed to deal at length with the cheapest method. The writer has conducted experiments with a motor-tyre pump and an old inner tube of a motor tyre, and except for the labour involved, this method was quite satisfactory; but it can hardly be recommended for a permanent installation in daily use.

For a hand apparatus for a single burner, the method described on page 48, and illustrated in Figs. 14-16, will probably be found the most satisfactory.

For hotels and such like establishments, which may have in use from two to twenty burners, some form of power-motor-compressor is undoubtedly the most economical, unless a public supply is available. If there is no electric current, a petrol or paraffin motor will answer the purpose just as well, and if power units are already in existence for other purposes, there may be sufficient margin to drive a small compressor, as even half a horse-power will supply a number of burners. The cost depends on local conditions, but unless the price of the current is very high, from one to two shillings a day should be sufficient. In any case, the large consumer can well be left to look after himself; but when we come to providing compressed air for oil firing for the bulk of the rate-payers of a city, there is no doubt it must be cheap, reliable, and constant. To supply cheap power it must be generated in large quantities, and the greater the quantity the cheaper the power.

To utilise cheap power without expense, it must be used direct, and not by the interposition of mechanical motion.

It is true, as stated above, hand power will light a burner. Hand power will also light an electric lamp; but it is obvious that this is not in the direction in which to look for its greatest development. Precedent has proved beyond question that hand power cannot compete with the generation of power in bulk in the matter of cost of production.

Now, in many towns and cities, such as Gosport, Eastbourne, Southampton, Cairo, Port Said, Bombay, Rangoon, Karachi, etc., compressed-air installations already exist for operating the pneumatic ejectors which drain these cities; and though the pressure is low, it is quite sufficient for combustion purposes in a kitchen range.

For draining cities in level districts, the compressed-air system has no superior. The one and only drawback that has made engineers hesitate to recommend it is the outlay on compressing plant and the cost of maintenance. But if a compressed-air system is converted into a self-supporting scheme in place of a burden on the rate-payers by the sale of the air for domestic firing, the last objection has disappeared.

Why should not the means of combustion for preparing the daily meal be supplied to city populations with no more trouble than water, gas, or electric light ?

If it pays a man to light his house from a power station, how much more will it pay him to cook his dinner, when the power costs but a fraction of that from which he derives his light ? There was a time when the laying of a gas-pipe to the smallest rate-payer in the city for the purpose of providing light was ridiculed, and it is not so long ago that electric light was regarded as a luxury for the rich, and an advertisement for up-to-date theatres. But the novelty of to-day is the accepted necessity of to-morrow ; and this means of illumination is as much a part of our daily lives as the electric tram and motor bus of every large city. Compressed air is an absurdly cheap secondary power when generated in large volumes at low pressure.

The fuel cost of compressing air to 100 lbs. per square inch with internal combustion engines is claimed to be as low as 1¼d. per 1000 cubic feet of free air compressed. This may be exceptional, but it is obvious that, at pressure of 20 lbs. to 30 lbs., 1d. would cover the cost.

However, it is better to base calculations on actual records than possible performances, and the figures given below are of exceptional interest.

The Cairo compressed-air system is a large one, comprising four sets of triple expansion steam air-compressing engines, and each engine is capable of compressing two million cubic feet of free air per day to a pressure of 22 lbs. to the square inch, which gives a working pressure of 20 lbs. to the square inch in distant localities. For the year 1916-1917 the volume of free air compressed was 573,240,000 cubic feet, at a maximum cost of £E. 6878.976, which equals a cost of 3d. per 1000 cubic feet of free air compressed.

The volume of air required for firing a kitchen range will vary according to size and the demand made on its heating powers ; but from ·119 to ·500 of a cubic foot of free air per minute, delivered at 20 lbs. to the square inch, should meet all requirements. Taking a mean figure of ·30 cubic feet per minute, this equals 18 cubic feet per hour or 216 cubic feet per 12 hours, or 78,840 cubic feet per year. After allowing for all expenses, it is clear a rate-payer can be supplied with air at a few pounds a year.

At such low pressure, leakage from cast-iron mains is not excessive, and, if instances of excessive leakage can be quoted, they are due to neglect and reluctance to spend money on maintenance ; but if the air can be sold and produce a revenue, this objection disappears. Service-pipe connections, like water and gas, may be of lead, which, being jointless, has no leakage, and an air-meter or other precaution would be taken to prevent householders from obtaining more than what they pay for.

OIL CONSUMPTION.

Experience shows that the domestic range consumes from 2 lbs. to 10 lbs. of fuel oil per hour, according to the size of the range and the amount of cooking.

In a small household 4½ lbs. per hour would probably be sufficient for seven hours per day. This equals 31 lbs. per day, or between five and six tons per year, which would equal ten to twelve tons of coal.

As to the price, that depends entirely on the country in which it is purchased. With oil-fields close at hand, it may cost £1 per ton; in unfavoured localities, where transport is expensive, £7 or £8 a ton may have to be paid.

In giving the above quantities of oil, the average figure has been given. In large ranges with heavy cooking, much more will be required; but if there is not a saving of 50 per cent. over coal, weight for weight, there is unnecessary wastage.

It is, of course, possible to inject quantities of oil into the furnace with poor results; on the other hand, with care and attention, and a suitable setting, a 60 per cent. saving can be attained. However, in cooking, reliability comes before all else, and there has been no instance of the Scarab burner failing to cook the dinner as far as the writer is aware, though these burners have been responsible for half a million meals to date (April 1919).

Though the application of oil fuel to the kitchen range is a simple matter, it should be installed by those who are familiar with the work, or disappointment and loss may result.

IV

APPLICATION OF BURNERS TO STEAM BOILERS

INEFFICIENT APPLICATION OF BURNERS.

Much of what has already been written concerning the application of liquid fuel to the kitchen range is also applicable to the large boiler for steam-raising purposes.

In many ways the problem is greatly simplified, largely owing to what has already been done in this direction, and the information and records which can be referred to on the subject.

In a large furnace the temperature can be maintained without difficulty, the draught controlled to a precise volume, the action of the burner carefully observed, and lastly, but not of least importance, a skilled attendant is always at hand to adjust the fuel and remedy any slight defects.

To develop the Scarab burner for large furnaces and steam-raising purposes was the natural result of the success obtained with the kitchen range, and it was soon obvious from experience that those features which made the burner efficient were magnified when applied on a large scale.

Though it is a common thing to depreciate the design of liquid-fuel burners as being of little consequence compared to the setting and arrangement of the furnace, there is no doubt some burners are more efficient than others, especially as regards reliability and range of power. Any crude form of burner can be fixed in the furnace of a portable or Lancashire boiler, and steam raised therewith, but whether it is efficient in operation or liable to damage the furnace is quite another matter.

It may deposit carbon, smoke in dense volumes, consume nearly as much oil as coal, and blow out as soon as an attempt is made to turn down the flame. In oil-producing countries, waste is only too often regarded with indifference, and the cheapest form of burner will have preference to a more efficient but expensive article. For instance, in a country like Egypt, liquid-fuel burners are in great demand for portable boilers which are used for driving irrigation pumps for a few months each year. The cultivator who requires a burner comes to town. He is totally ignorant of efficiencies, and it is useless to explain to him that by purchasing a more efficient burner he will save so much per year. He simply wants an apparatus that will generate steam for a few months, and every extra pound spent he considers as so much less profit from his crops, therefore in nine cases out of ten he selects the cheapest form of burner, no matter how crude or inefficient. In all probability it is indifferently set up, with a few loose bricks for the flames to play on. He will run his boiler with the furnace door open, and the tubes are cooled by the inrush of air, so that carbon often forms, owing to low temperature; and if full power is required smoke pours from the chimney. Possibly there is a saving of 20 per cent. over coal, but more likely 10 or 15 per cent.

When hundreds of such plants are in use, the great waste will be realised. The difference between burning oil under such conditions by native cultivators and an up-to-date power station is enormous, and hard to believe till actually experienced.

With the exception of the Royal Navy, oil firing is not often applied for steam-raising purposes in the British Isles, but in America, Russia, and the East it has displaced coal in many localities. This is, of course, due to fuel oil being sold at such a price that it is the cheaper fuel to purchase.

There are three distinct forms of liquid-fuel burners in use for steam-raising purposes :—

TYPES OF BURNERS.

1. The pressure-jet system.
2. The steam-injector system.
3. The steam or air-spray system.

1. The pressure-jet system has been placed first, as it has reached the most advanced stage of development, and is the most suitable for marine purposes.

2. The steam-injector system is the most widely used for stationary boilers and locomotives, and there are more varieties of this form of burner than any other. Though they may differ greatly in design, their action is practically the same.

3. The spray type of burner is probably the oldest form of atomiser, and is still largely used on locomotives, and for excessively heavy and viscous oils is to be preferred to the other types. It is much simpler in construction, has no fine working parts, and, if correctly set, will equal, if not surpass, the other types in reliability and simplicity of operation.

1. In the pressure-jet system the oil is pre-heated before use, to a high temperature, by means of steam coils. It is then passed through fine filtering material and forced by steam pumps through a minute hole, controlled by a needle valve, into the furnace. In order that it should be diffused in fine spray, a pressure of 80 lbs. or 100 lbs. the square inch is required. To maintain the pressure duplicate steam pumps are installed, and for the best results forced draught, produced by power

fans, must be provided. The tendency of all small orifices, exposed to high temperature, through which fuel oil is passing, is to choke up, either from carbonisation or foreign matter.

As before stated, the highest evaporative efficiency has been obtained by this means ; but the system is complicated and expensive to install, and for locomotive and small powers practically never utilised.

2. The essentials of the steam-injector burner have already been described on page 23. They are unsuitable for marine purposes, as from 2 per cent. to 6 per cent. of the steam generated is lost in the furnace ; and this amount of water cannot be made good at sea. They are also liable to choking and carbonisation, and arrangements for blowing steam through the oil passages are usually provided. The system is, however, exceedingly simple and cheap to install, as the oil flows by gravitation to the burner, and the steam jet will induce a fierce draught, which is necessary for good combustion.

3. In the spray type of burner the oil and steam are entirely separate. The oil flows by gravitation from a nozzle, and the steam or compressed air either picks up the oil, by issuing from a narrow orifice beneath the oil, or impinging on the lip of the oil orifice, as the liquid tends to flow over the edge.

CONDITIONS FOR COMBUSTION.

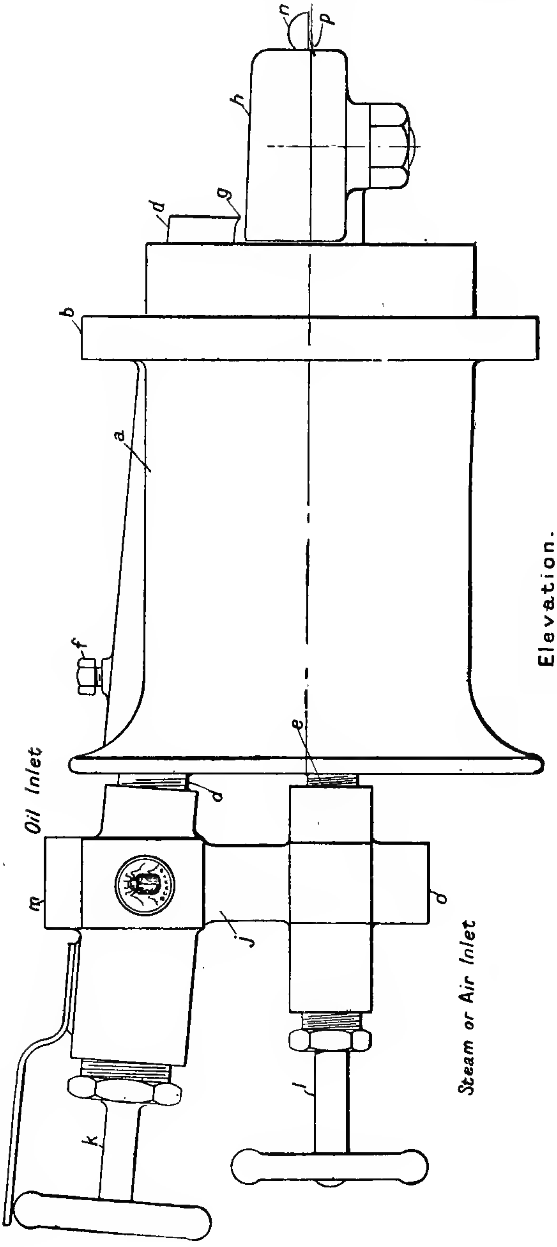
Now, whatever type of liquid-fuel burner is used for steam-raising purposes in a boiler furnace, the conditions we wish to arrive at are the same. That is to say, the object is to make the maximum use of the furnace for combustion purposes ; to shorten the flame as much as possible, and bring about the complete mixture of air and pulverised oil at the earliest possible moment. Everyone knows a good stoker keeps his fire well forward ; that is, the combustion of the gases given off by the coal should not take place right at the back of the furnace, or smoke and poor efficiency will result. In the same way, only of more importance, is it that the products of combustion of liquid fuel should not be driven to the back of the furnace.

What we require in a fluid atomiser burner, before all else, is pressure and velocity of the fluid to pulverise the oil, and a jet of width, depth, and little length. A burner that will comply with this condition, whether of the injector or spray type, will give a better efficiency than one that does not. At the same time, the primary air supply should be in the form of induced draught, and so arranged that it cannot come in contact with the walls of the furnace and boiler heating surfaces without being heated by the flame.

LARGE BURNER DESCRIBED.

Figs. 17-18 show a large Scarab burner for steam-raising purposes. Fig. 17 shows a side elevation, and Fig. 18 an end view facing the nozzle.

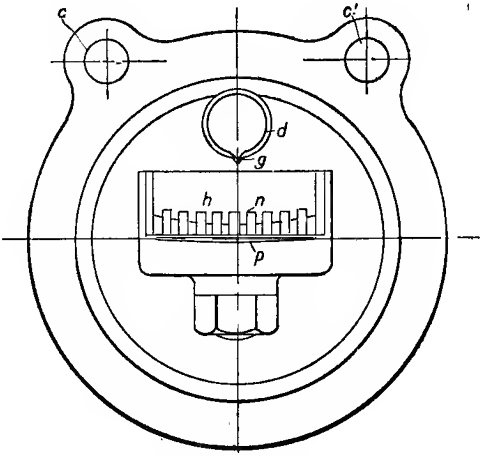
Briefly, the burner consists of a cast-iron cylindrical casing *a*, on which is cast a flange *b*, with two bolt-holes c, c^1, for holding the burner in place. Through the casing *a* passes the oil-pipe *d* and the compressed-air or steam pipe *e*, supported by a web not shown, but held in place by the set screw *f*. These pipes terminate in a lip *g*, and a nozzle or weir *h* at one end of the casing *a*, and in a header *j* common to both pipes at the other. In this header *j* is a regulating valve *k* for the oil, and a similar valve *l* for the air. The oil enters the header from the upper inlet *m*, passes down the pipe *d* till it falls from the lip *g* into the nozzle or weir *h*, and flows over the serrated edge *n*.



Elevation.
FIG. 17.

The compressed air or steam enters the bottom of the header at *o*, and issues from the orifice *p* beneath the serrations *n* of the weir *h*, impinging on the under-surface, which spreads the jet and carries the oil passing over and between the serration *n* into the furnace.

With the ignition of the spray a fierce draught is set up through the casing *a*, atomisation is complete, and a steady luminous flame of dazzling brilliance is maintained as long as the flow of oil and steam continue. It will be observed the pipe *d* has a full way, and cannot choke, and as the valve *k* can be completely withdrawn when the burner is fixed, a clear view can be obtained throughout the length of the pipe. The induced draught through the casing *a* prevents over-heating of the oil-pipe orifice and the nozzle, thus preventing carbonisation, and the air is mixed with the pulverised oil as it leaves the burner nozzle, which shortens the flame, and heats the air before being distributed in the furnace.



End View

Fig. 18.

Though the principle on which the large burner is designed is the same as that adopted for the kitchen range, it was found desirable to split up the stream of oil, and ‘ dish ’ the upper surface of the nozzle, so that a continuous stream of oil is maintained when it is desired to reduce the flame to its smallest dimensions.

The Scarab burner possesses certain merits that are absent in other designs. *The outstanding feature* is that it will not choke, as all foreign matter is sprayed into the furnace with the oil and instantaneously consumed. It will run week after week, month after month, without removal, and can be examined internally when fixed in position. The flame—that is, the power of the burner—can be reduced or expanded over wide limits, so there is no necessity to periodically extinguish and rekindle the fire, to avoid raising steam too quickly. Though rated at 120 H.P., it may be reduced to 20 H.P. or less, and raised to 250 H.P. or more. It gives a short, thick, fat flame, within a few inches of the nozzle. It will burn the most viscous quality of oil as easily as that quality which comes up to the Admiralty specification.

It is so designed and applied that the primary air supply is induced to impinge on the hottest part of the flame, which not only ensures the complete mixture of air and fuel at the earliest possible moment, but ensures the maximum use being made of the furnace.

Such burners have been successfully firing boilers week after week, month after month, night and day, and only extinguished when it is desired to lay the boiler off for cleaning.

In action they are extremely sensitive, but easy to manipulate, and the independent regulation of the oil and steam with the sight feed is appreciated by the boiler attendants.

FIRING WATER-TUBE BOILER.

Figs. 19-22 show a group of four 150 H.P. Babcock and Wilcox water-tube boilers, to which the Scarab induced draught oil-firing system has been applied.

Before designing the arrangements for a large installation of this description, local conditions must be taken into consideration. That is to say, method of transport to the power-house, position of oil-storage reservoirs, method of raising oil to the feed-heating tank, the most suitable position for this tank, and system of distributing the oil to the burners.

This installation is for supplying steam to the air-compressors for draining the city of Cairo, and for two or three years the boilers were coal-fired before their conversion to liquid fuel.

The site of the storage reservoir (150 tons capacity) having been decided on, the position of the ejector, pipes and feed-tank have been arranged with a view to securing the maximum efficiency in working and economy in construction.

The essential features and requirements of the installation which have been kept in view are :—

1. A simple and reliable apparatus for raising the oil from the storage reservoir to the feed-tank.

2. Arranging the feed-tank and all pipe work in such a way that all boiler brick-work, flues, economiser, etc., can be rebuilt without interfering with the installation.

3. The efficient heating of the oil, so that the highest temperature is attained as the oil arrives at the boiler face.

4. Utilising whenever possible material on hand or what can be obtained locally.

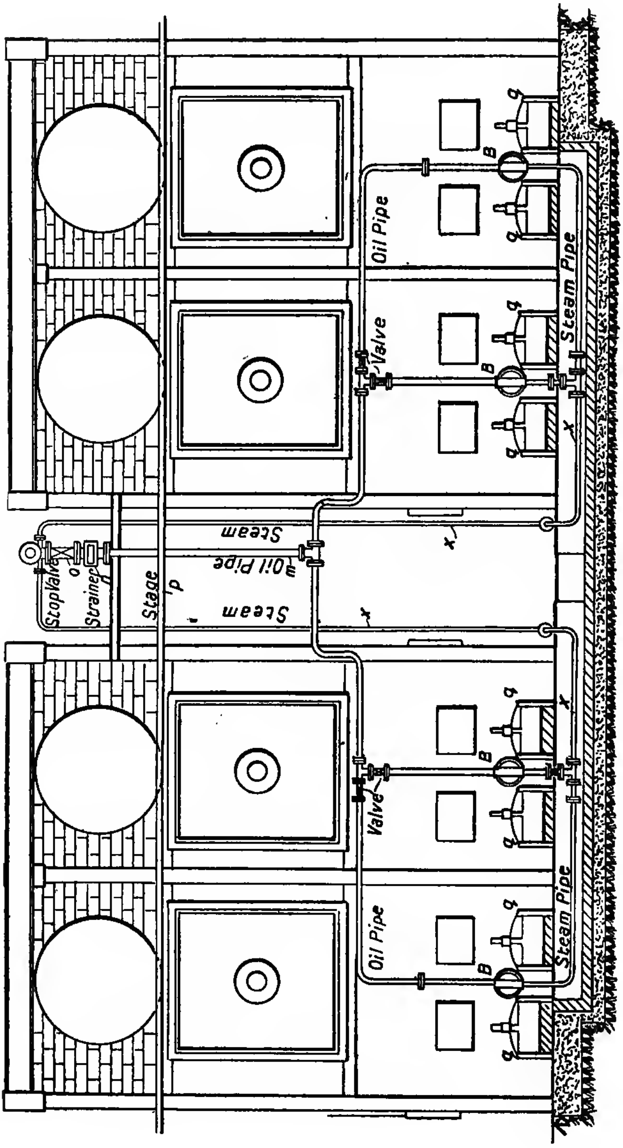


FIG. 19.—FRONT ELEVATION.

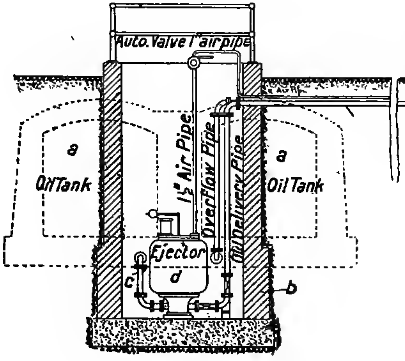
It must be borne in mind that, owing to the war, Egypt, like other countries, was thrown on her own resources, and ejectors, stop valves, fittings, etc., had to be designed and made locally. Fig. 19 is the front elevation of the boilers. Fig. 20 is a section through the ejector chamber with a cross-section of the oil reservoir dotted in. Fig. 21 is a sectional elevation of boiler-house and furnace. Fig. 22 is an elevation of the feed-tank in front of the window, facing the four boilers.

STORAGE RESERVOIRS.

One of the chief items of expense in installing oil fuel at a power-station is the storage for the oil. A coal bunker costs nothing but the fence or wall, to prevent theft, and in most cases the cost of a shelter is dispensed with. It is one of the few initial expenses in which coal can claim the advantage.

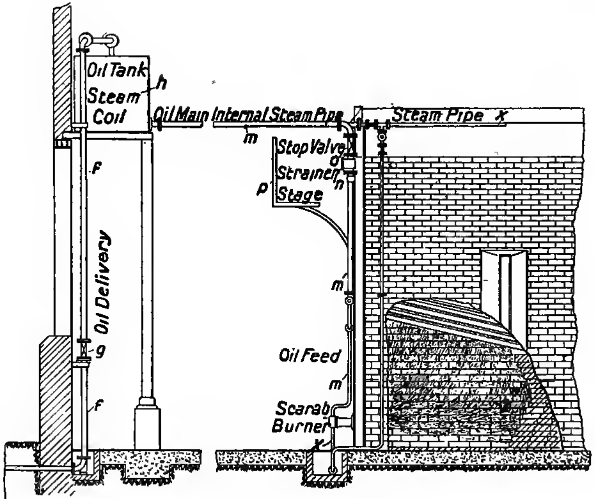
Owing to the searching properties of petroleum, many engineers will only sanction sheet-iron reservoirs, but the leakage from a properly constructed masonry reservoir is so slight, if any at all can be detected, that there is no reason why they should not be built if there is a large saving in first cost. It is advisable to have a reservoir that will hold not less than a month's supply, and in cases where transport is irregular or uncertain, two months' supply should be provided. In building a masonry reservoir, the site must be carefully selected, and on no account should the foundations rest on made-up ground. The depth of the excavation will depend on the size of the tank and the extent of ground available, but it is better to have a large area with little depth, in order that the pressure per square inch may be reduced as much as possible. If a railway siding is near at hand so much the better, and if there is choice of position between the power-house and the siding, the site adjacent to the siding should be selected, as the oil will flow by gravitation from the tank wagons, probably by temporary pipes or shoots, whereas permanent arrangement can be made for forcing the oil from the reservoir to the supply tank in the boiler-house, and a few yards of extra pipe is of little consequence.

Reinforced concrete, with a lining of blue bricks set in two-to-one cement mortar, is excellent material for a reservoir. This should be rendered with cement of the best quality, with the addition of some waterproof mixture or a final coating of shellac. The workmanship must be of the best, and care taken that the bricks are well bedded in the cement and the concrete well rammed in place. It is better to divide the tank into several compartments by walls, and construct the roof of a series of brick arches, a few inches below ground level, which should be well rendered with cement mortar before being covered in. In finishing the floors a fall should be given to one end, so the compartments can be completely drained and cleaned out when required, and an outlet provided from each chamber at the lowest point. The most convenient form of outlet is a cast-iron pipe, with creeping collars buried in the foundation concrete and turned up into the tank. By this means a perfectly oil-tight joint can be made, and any creeping of the oil outside the pipe is prevented. To draw off the oil either a steam pump or pneumatic ejector is required. This is placed in a chamber adjacent to and below the level of the reservoir, as shown in Fig. 20, so the oil flows by gravitation into the suction pipe. A by-pass should also be provided in the outlet pipe for draining off any water that may collect. When the oil is of a very heavy viscous nature, steam piping must be introduced into the outlet end of the reservoir, or much



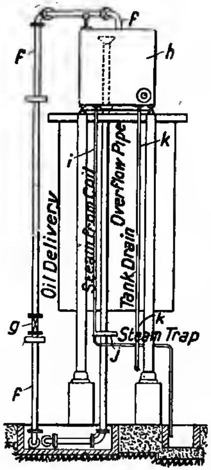
Ejector Chamber

FIG. 20.



Sectional Elevation

FIG. 21.



Elevation on Wall

FIG. 22.

difficulty will be found in cold weather in making the oil flow. When no railway siding is available from which tank wagons can be directly run off into the power-house reservoir, the oil is often transported in iron drums, holding about fifty gallons each. It need scarcely be pointed out that the labour involved in handling and employing hundreds of such drums every week, is both costly in time and labour. Indeed in cold weather, without arrangements for forcing the oil from the drums by compressed air, they will take many hours to drain. In any case a special platform must be arranged above the reservoir on which a number of drums can be placed to drain at the same time. Under such conditions the 'cleanliness' of oil fuel is conspicuous by its absence, and it is fortunate that this system is rarely met with, except as a temporary expedient, when for some reason or other permanent arrangements are delayed or the demand for rail tank wagons has outrun the supply.

Arrangement of Oil Supply.

From the storage reservoir *a* (Fig. 20) the oil gravitates, by means of a cast-iron pipe *c*, controlled by a stop valve, to the fifty-gallon ejector *d*, located in the chamber adjoining the reservoir *a*. The ejector is filled by gravitation under atmospheric pressure, and is at such a level that the reservoir *a* can be completely emptied. It is of the automatic type, operated by compressed air at 22 lbs. square inch; the ejector having filled and discharged, the oil passes up the pipe *f*, past the regulating valve *g*, into the feed-tank *h*. This tank is supported on two cast-iron pillars, and located in such a position that there is an equal distribution to the boilers, through a minimum length of pipe. The feed-tank *h* contains a steam coil for heating the oil, and a drain pipe *i*

(Fig. 22) carried through the bottom of the tank *h*, controlled by a steam trap *j* for preventing the accumulation of water in the steam coil, and a pipe *k* enables the tank *h* to be drained of oil and the internal fittings examined.

A float, with guide and pulley attachment (not shown), is provided for indicating the quantity of oil the tank contains, and a distributing plate is fixed beneath the oil inlet in order that the cold oil may not plunge to the bottom.

The steam-pipe *x* for heating the oil is taken from the reflux valve cover, on the steam main, or other suitable point common to all the boilers, and by means of a gland and stuffing-box passes through the oil-pipe *m* to the steam coil in the tank *h*. Immediately below the bend which forms the stuffing-box is fixed a strainer *n*, controlled by a stop valve *o*, and, as the existing boiler stage *p* is conveniently situated, the straining medium can be replaced when the boiler is working.

As the oil from the feed-tank takes some minutes to pass from the tank *h* to the valve *o*, it cannot fail to be at a high temperature, provided the internal pipe is full of steam. Below the strainer *n* the oil-pipe *m* branches to the right and left by means of a tee piece, and flows to each of the four Scarab burners marked B. The steam-pipe (Fig. 19) is carried in a trench below floor-level, and then up to the level of the steam-pipe for heating the oil. By this arrangement a single feed-tank and coil is sufficient for four or more boilers, the duplication of valves and pipes is avoided, and any one of the four boilers can be started up independently of the others. In a large power-station there is always steam in one of the boilers.

The primary air supply is induced through the burner B, and the secondary air supply by the ash-pit regulators *q*, which must be so constructed that they can be accurately adjusted. The fire-doors are closed and made air-tight, and care must be taken that *all the air* which enters the furnace is under complete control.

Fuel Consumption.

Though reliability is of first importance in an oil-fuel burner, economy is none the less necessary, as in burning many tons of fuel a day 5 per cent. and 10 per cent. saving will amount to a very large figure per year. With liquid fuel it is possible to obtain very high efficiencies under trial conditions, but what we want to know are the results in daily practice, and to ascertain such results it is necessary to draw comparisons.

For this purpose numerous daily records have to be taken, and the tabulated results carefully considered. One type of burner may permit of better regulation of the oil and draught, which will give better results, while in another type such good results may not be obtained from omitting such details. The figures given below are obtained from comparing the Scarab burner with a type largely used in America and by the Egyptian Government, owing to its great merits. Like all good burners, it is of extremely simple construction, and consists of two compartments, one above the other. The upper compartment is reserved for the oil and the lower for the steam, a pipe for the oil and a pipe for the steam being screwed into the upper and under side of the burner respectively. The opposite end of the burner terminates in two wide horizontal slots. As the oil flows from the upper slot, it is turned into spray by the jet of steam which issues from the lower slot.

In all figures given, it must be understood that there is no pre-arranged trial, and the dates selected for comparison are those on which the engine ran nearly the same number of revolutions. Again, in compressing air for a pneumatic-ejector system, the fluctuations in speed are great, and this more than anything else prevents high efficiencies. For economical results uniform speed is a necessity. First-class steam-engines will run on 10 lbs. of steam for 1 H.P. per hour, but the engines in this case consumed 21 lbs. of steam approximately per 1 H.P. per hour. The two types of burners are distinguished by the 'Scarab' and 'Slot.'

TABLES OF COMPARISON.

The consumption of fuel oil per indicated horse-power per hour of a triple-expansion air-compressing engine, supplied by Babcock and Wilcox water-tube boilers, fitted with a Scarab burner and a Slot burner, compared to coal firing, is now given :—

Date.	Time.	I.H.P.	Fuel.	Fuel per I.H.P. lbs.	Burner.
May 2, 1918 . .	12 hrs.	135·5	Coal	1·26 kilos=2·52	...
May 7, 1918 . .	12 hrs.	136·3	Oil	0·89 kilos=1·95	Slot
April 7, 1919 . .	12 hrs.	141·0	Oil	0·76 kilos=1·67	Scarab
May 7 and 8, 1918 .	48 hrs.	140·0	Oil	0·85 kilos=1·87	Slot
May 7 and 8, 1919 .	48 hrs.	151·0	Oil	0·73 kilos=1·60	Scarab

In the above table the greater horse-power is slightly in favour of the Scarab burner, but the following results may be deduced : a saving of 30 per cent. and 40 per cent. of oil fuel over coal, and 14 per cent. of the Scarab burner over the Slot type.

The longer the period over which figures are taken, the more accurate is the average likely to be, as the conditions of running in the twenty-four hours vary greatly. The next set of figures is based on the consumption of oil per revolution of the engine, with the two different types of burners.

Date.	Time.	Engine Revolutions.	Total Oil Kilos consumed.	Revolutions per Kilos of Oil.	Kilos per Revolution.	Burner.
April 29, 30, 1919 .	2 days	231,609	5,484	42·23	0·236	Scarab
June 17, 18, 1918 .	2 days	232,520	6,254	37·17	0·268	Slot
April 21, 22, 1919 .	2 days	224,600	6,219	36·11	0·276	Scarab
June 9, 10, 1918 . .	2 days	219,820	6,428	34·19	0·292	Slot
Jan. 14-16, 1919 . .	3 days	341,672	10,890	31·29	0·319	Scarab
Jan. 11-13, 1919 . .	3 days	320,563	11,880	26·91	0·371	Slot
April 29, May 6, 1919	8 days	892,074	22,183	40·21	0·248	Scarab
May 5-12, 1918 . .	8 days	880,723	23,323	37·76	0·264	Slot

These figures show an average of 10·7 per cent. in favour of the Scarab burner.

The next table shows the weight of oil burnt by the two types of burners to compress 1000 cubic feet of free air.

Date.	Time.	Air Pressure.	Volume of Air in cubic feet compressed.	Total Oil in Kilos.	Oil per 1000 ft. of air. Kilos.	Burner.
Jan. 11-13, 1919 .	3 days	23 lbs.	5,693,198	11,880	2·07	Slot
Jan. 14-16, 1919 .	3 days	23 lbs.	6,068,094	10,890	1·82	Scarab
Nov. 24-29, 1918 .	5 days	23 lbs.	13,557,451	22,288	1·64	Slot
Feb. 23-28, 1919 .	5 days	24 lbs.	13,593,575	20,696	1·52	Scarab
April 27, 1919 .	12 hrs.	23 lbs.	937,976	1,304	1·38	Scarab
March 16, 1919 .	1 hour	24 lbs.	83,560	110	1·32	Scarab

The regulation of the secondary air supply is of vital importance to economy. Correctly adjusted, a consumption of 0·73 kilos (1·60 lbs.) per I.H.P. per hour was easily maintained ; whereas, with inexperienced hands 0·89 kilos (1·95 lbs.) are required.

These figures are given purely for the purpose of comparison. With large powers, first-class engines, and uniform work, ·95 lb. or 1 lb. of oil per I.H.P. is not unusual, and no doubt on pre-arranged trials this can be improved on.

Furnace under Fire.

On first inspecting a water-tube boiler of the Babcock and Wilcox type to which the Scarab burner has been applied, surprise is often expressed. There is no fierce hissing of the steam jet, or roar of the air entering the furnace. There is little indication that the boiler is under full steam.

The secondary air-supply regulator covering the ash-pit openings is scarcely open, and to all appearance the furnace is closed, but a fierce draught can be felt with the hand passing through the burner casing. On placing the eye level with the burner, the process of pulverising the oil is plainly visible. A cloud of gold dust with a brownish centre, surrounded with a luminous flame of dazzling brilliance, appears to burst spontaneously from the nozzle of the burner. Through the spy-holes in the front of the furnace no tongues of flame can be seen, no section of the walls is visible, the entire chamber is filled with an opaque mass of fire of intense brightness. From the cleaning doors in the side of the boiler brick-work a more or less transparent flame, tinged with violet, fills the space between the tubes. Combustion is complete, there is neither smoke nor smell, and the cap of the chimney-stack rises into a clear atmosphere, with possibly a wisp of smoke from time to time, as some adjustment is made to the burner.

With careful regulation, there is no reason why heavy smoke should ever be made. Smoke may be caused by insufficient air for combustion purposes, by forcing the burner in excess of the capacity of the furnace, by water in the oil, and by the temperature being too low.

In situations where heating of the storage reservoir takes place by steam-pipe, or if moisture can creep into an underground reservoir, water is more frequently the cause of smoke than is usually supposed. If any quantity is injected into the furnace, it will put the fire out, and, if this is at all frequent, liable to damage the boiler from sudden alteration in temperature. If the burner is set correctly there is no fear of damaging the boiler. On the contrary, the tubes will outlast a coal-fired boiler.

Though so easy to apply and simple to operate, it is as well to repeat that with unsuitable arrangements it is possible to inject tons of oil into a furnace with very *poor results*, and, in some cases, damage the furnace crown or tube plates.

It must not be forgotten that a water-tube boiler under oil firing is extremely sensitive, and though manual labour is practically abolished, it must be substituted by intelligence and care, if the full benefit of oil firing is to be obtained.

ADVANTAGES OF SINGLE BURNER.

Some engineers favour several small burners in place of a single jet, but a brief experience is enough to show the great advantage of a single spray. If smoke issues from the chimney or the steam pressure falls, it is difficult for the fireman to ascertain which burner is at fault, and he will be at a loss to know which to adjust.

Again, with a number of burners, valves and pipe-work are duplicated, joints are multiplied, and the arrangements for the admission and distribution of air for combustion are more complicated. A single burner of wide range of power is easier to control from every point of view, and is capable of giving a higher efficiency in daily work with less attention. That is to say, less adjustment is required, there is better control of the temperature, efficient combustion is more easily maintained, and the steam pressure is less liable to fluctuation. That the pulverisation of the oil is as complete with a well-designed large burner, as with a small one, there can be no question, and leaves nothing to be desired. If one burner will do the work efficiently, it is false economy to employ a larger number, both in respect to initial expense and maintenance.

SOLID AND LIQUID FUEL BURNT TOGETHER.

Though oil is practically never burnt with coal in oil-burning countries, the combination has been resorted to in England, since many power-users found the quality of the coal obtainable under war conditions was so poor that the required steam pressure could not be maintained—that is, the evaporative efficiency of the fuel was too low.

Though fairly satisfactory results may be obtained by injecting a limited quantity of liquid fuel into a coal furnace, the conditions do not permit of those high efficiencies which are obtainable with oil alone.

In the coal-fired boiler, the fuel is often too close to the boiler tubes or furnace crown to give sufficient area for the complete combustion of the liquid fuel, with the result that much smoke occurs and unburnt gases escape to the chimney.

The importance of having sufficient area for proper combustion cannot be over-estimated, and that is why forcing the furnace beyond its capacity so often results in dense volumes of smoke being given off.

Again, the temperatures necessary for the efficient combustion of coal and oil are not the same, and unless the fire-bars are kept very evenly covered, uneven heating of the furnace may occur, which is liable to damage the boiler.

In some designs of boilers it would no doubt be possible to lower the level of the fire-bars, but this would mean the expense of new furnace fronts, and as likely as not the loss from an unsuitable coal furnace would be greater than the gain from a more efficient oil furnace, especially so if the boilers are hand-fired, as the cooling of the furnace each time the fire-doors are opened for stoking purposes is a serious matter. If a power-house is compelled to use both liquid and solid fuel, it is far more satisfactory to convert half the plant to oil, and reserve the other half for coal firing. The condition for the best efficiencies are so opposite that they cannot be reconciled on the same grate. In cases where industrial works or power-stations either possess their own residues from gas plants or can easily obtain a limited quantity, but insufficient to fire a single boiler, it is, of course, better to burn such fuel in conjunction with coal than throwing it on the scrap-heap. A limited quantity can be injected above the coal, and extra steam pressure maintained, but 'efficiency' from the oil-burning point of view must not be too eagerly expected.

EFFICIENCIES OF BOILER AND BURNER.

The efficiency of the numerous designs of coal-fired boilers has always been a matter of controversy. Each maker claims some particular merit for his own design and construction, but when it comes to oil firing, the water-tube type with massive brick fire chambers is hard to surpass. In comparing the efficiencies of boilers under oil firing with various forms of burner, comparisons should only be drawn between those of the same type, as it will be readily understood that a trial conducted on an inefficient boiler will not give good results, no matter what the type of burner may be. In making claims for the 'efficiency' of one burner compared to another, the precise conditions, such as type of boiler and power developed, must be ascertained. The greater the power the more favourable it is to a high efficiency. Again, in the evaporation test the temperature of the feed water entering the boiler must be carefully recorded, as a much larger consumption of fuel is required if no economiser is used, and only the warm water from the air-pump overflow is used as the boiler feed.

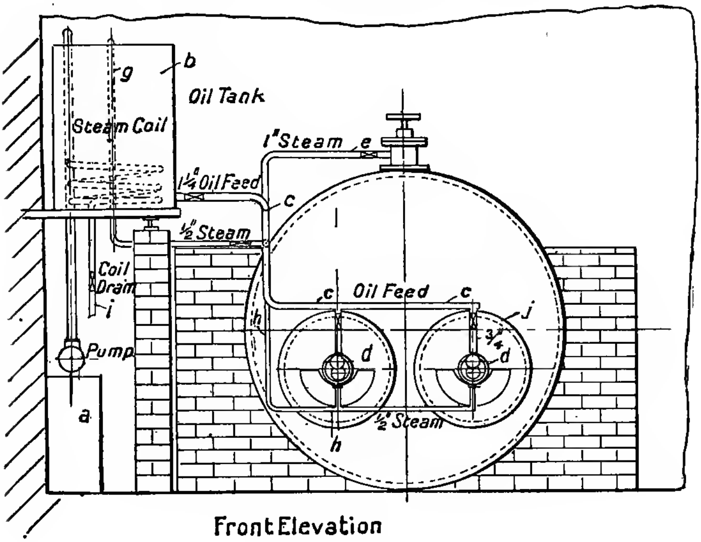


Fig. 23.

Firing Lancashire Boiler.

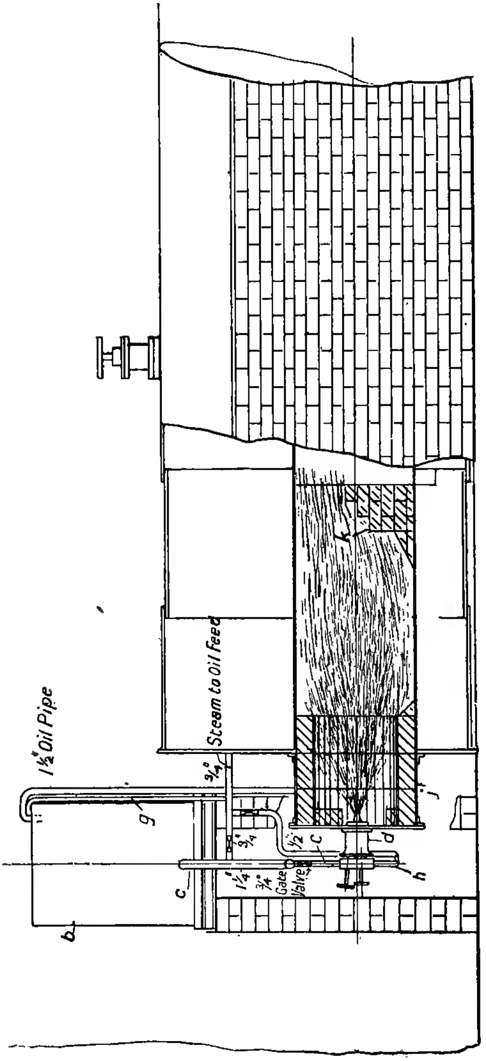
Figs. 23-25 show how the Scarab burner is applied to a Lancashire boiler.

Fig. 23 is the front elevation.

Fig. 24 is a sectional elevation.

Fig. 25 is a plan showing the arrangement for the oil supply.

The installation consists of a donkey-pump *a* which



Sectional Elevation

FIG. 24.

draws the fuel from a storage reservoir, outside the building, and delivers it into the oil-tank *b*, which is placed at such a height that the oil will flow by gravitation, through the pipe *c* to the burner *d*. A steam connection *e* is made to the main stop valve or other suitable point, and supplies steam to the donkey-pump *a* by the pipe *f*, and to the steam coil in the oil-tank *b* for heating the oil by the pipe *g*. The pipe *h* conveys steam to the burner *d*, and the drain *i* is for clearing the coil of water.

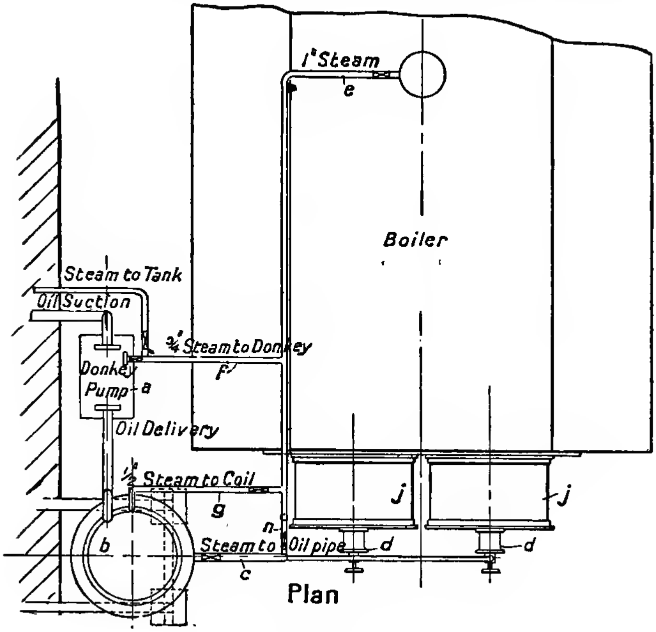


FIG. 25.

In this type of boiler there is no brick furnace, and in order to increase the length and maintain the high temperature necessary for good combustion, when a small power is required, the extension piece *j* is attached to the front of the furnace and lined with fire-brick. A fire bridge *k* is also built up at the far end of the furnace to prevent the escape of unburnt gases, and assist in the process of complete combustion. The primary air supply passes through the burner, and the secondary air supply is under perfect control, by means of a regulator, which can be either completely closed or entirely removed for lighting-up purposes. Fire-bricks prevent the over-heating of the furnace front, and an extension piece, designed and applied as shown, effectually prevents cold air from coming in contact with the walls of the furnace, thereby causing unequal expansion of the plates.

The Scarab burner is attached to the front of the plate by two bolts, and the steam connection *n* (Fig. 25) to the oil-pipe *c* is for the purpose of warming the pipe in cold weather if the boiler happens to be in intermittent use.

Such boilers as shown in this drawing vary greatly in size and details of design; and before installing oil-fuel apparatus the average condition under which they work should be considered. Though the setting shown is suitable for the Scarab burner, it does not follow that it will suit all variations; in fact, there are some types of injector burners which require a longer extension piece, while there are others that are sometimes placed in the existing furnace front.

Whatever the arrangement may be, the essential points which are necessary for good combustion and efficiency should always take precedence over the saving of a few pounds on the cost of the installation.

The average cylindrical boiler is no doubt much improved for oil firing by fixing an extension piece on the furnace front. It increases the space for combustion, and tends to prevent local over-heating. It must be remembered that the centre of the flame is intensely hot a few inches from the burner, and the pulverised oil should not come in contact with the iron before the initial stages of combustion have taken place. In such boilers it is often difficult to maintain the high temperature required for good combustion if the boiler is being run at only a small percentage of its capacity. There is nothing to retain the heat, and if the air supply is not almost entirely shut off the furnace rapidly cools.

ADVANTAGES OF BRICK FURNACE.

On the other hand, with substantial brick chambers, which are possible in the water-tube type of boiler, the furnace can be ‘banked’ almost as effectually, if not quite, as with coal, owing to the glowing mass of brickwork retaining the heat and keeping up the steam pressure. The moment the flame is extinguished, the air regulators must be immediately closed, as the cold air rushes into the furnace and plays directly on the tubes or plates. When this is realised, the importance of having doors and regulators as air-tight as it is possible to make them will be appreciated.

The average damper is by no means a good fit, and as other boilers are invariably connected to the same flue, the hot air rapidly escapes. Large boilers of this type will take forty-eight hours to cool down, and on lighting up from cold, it will be at least twenty-four hours before the whole of the masonry has attained its highest temperature and the furnace can be utilised to its fullest capacity. Steam can be raised in an hour or less, though it is not advisable to do so unless it is an urgent matter, but the maximum cannot be generated. To be more explicit, the boiler can be forced to a much greater extent after twenty-four hours’ use. With high steam pressure and liquid fuel, the power which can be derived from a well-designed water-tube boiler rated at 150 H.P. is little short of extraordinary. When emergencies arise, and a boiler is required to generate every ounce of steam, regardless of the quantity of the fuel burnt, there are no opportunities to carry out tests and take readings, and the power developed is a matter of conjecture, but a water-tube boiler converted from coal to oil will increase the rated capacity by nearly 50 per cent.

In some respects it is easier to run a battery of boilers than a single unit, as it ensures steadier conditions. The steam pressure is not so sensitive, and automatic boiler feed valves can be used with success on several boilers at once. With a single boiler the regulation of the feed water is a matter of delicate adjustment, and it requires both skill and intelligence to adjust the oil feed to the furnace and the water feed to the boiler, so that the steam pressure will remain constant. If the demand on the boiler is irregular, constant watchfulness is a necessity to prevent the fall of the steam or the blowing off of the safety valve. However, with a single boiler, the fireman knows the exact condition of his burner and furnace, and should be able to regulate his draught so that a faint wisp of smoke comes from the chimney stack—the best indication that too much air is not entering the furnace to cool the boiler, or too little air for good combustion. With a large number of boilers it requires practice to tell which one is at fault.

FIRING PORTABLE LOCOMOTIVE BOILER.

Figs. 26-29 show how a portable boiler of the locomotive type is oil-fired with the Scarab burner.

Fig. 26 is a sectional elevation through the fire-box.

Fig. 27 is a sectional elevation from the furnace end of the boiler, with the front removed, so the brickwork can be seen.

Fig. 28 is an elevation showing the burner fixed in the back end of the furnace.

Fig. 29 is a plan with a portion of the barrel removed, so the burner can be seen.

The hand-pump *a* draws the oil from the storage reservoir outside the building, and delivers by the pipe *b* into the feed-tank *c*. From the tank *c* the oil flows by gravitation through the pipe *d* to the burner *e*. A steam connection *f* is made to the stop valve, or other suitable point on the boiler, and conveys steam to the heating coil in the tank *c* by the pipe *g*. The steam-pipe *h*, connected to the oil-feed pipe *d*, is for the purpose of warming the oil-pipe in cold weather, before the burner has been lighted. The burner *e* is supplied with steam by the pipe *i*, and the pipe *j* is for draining the steam coil of water.

It will be observed the burner is placed below the level of the foundation ring. By this means greater use is made of the fire-box volume, and it is unnecessary to pierce the water space in front of the furnace. The travel of the flame is also facilitated by this arrangement, and the brick setting simplified.

In railway locomotives, liquid-fuel burners are often placed in front of the fire-box, as they can, of course, be more easily manipulated from such a position; but in portable boilers used for agricultural purposes, such as shown in the illustration (Fig. 26, page 86), there is no object in going to the extra expense. The boiler shown is a large one for this type; but the great majority of such engines range from 10 to 20 H.P., and the fire-boxes are very much smaller than the example shown; but this is of no consequence to the efficient working of the Scarab burner, as it can always be 'set back' to get sufficient length of flame, if it is situated below the foundation ring.

There are many ways of setting burners in locomotive furnaces, and to get the maximum power from the boiler without smoke, or deposit in the tubes, it is very necessary to make full use of the fire-box volume. Space on a locomotive is restricted, and it is not quite such a simple problem as those types of boilers having large brick furnaces.

The Scarab burner is working successfully fixed in the front of two large boilers of the locomotive type, and, in cases where the conditions make such a setting desirable, this method can be arranged.

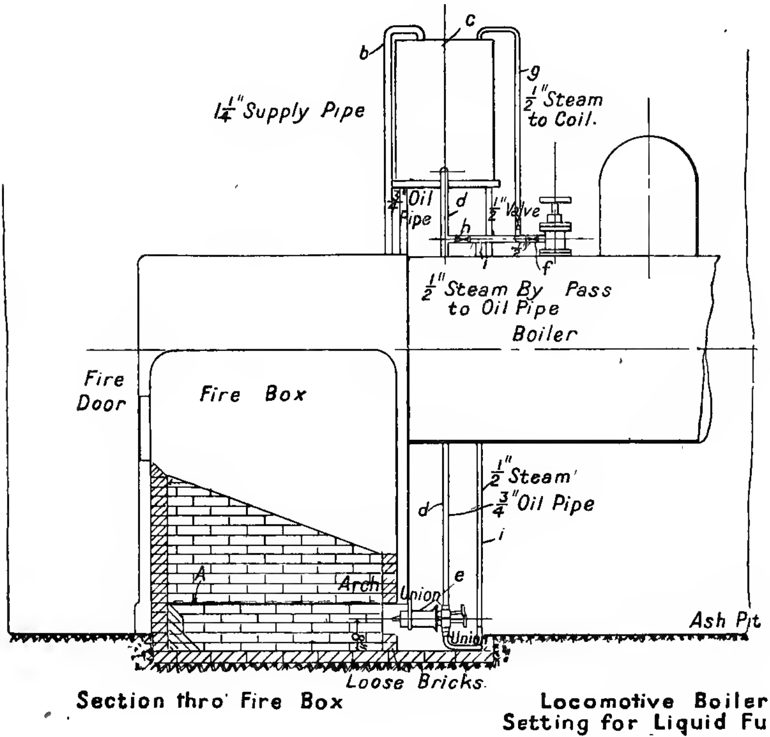
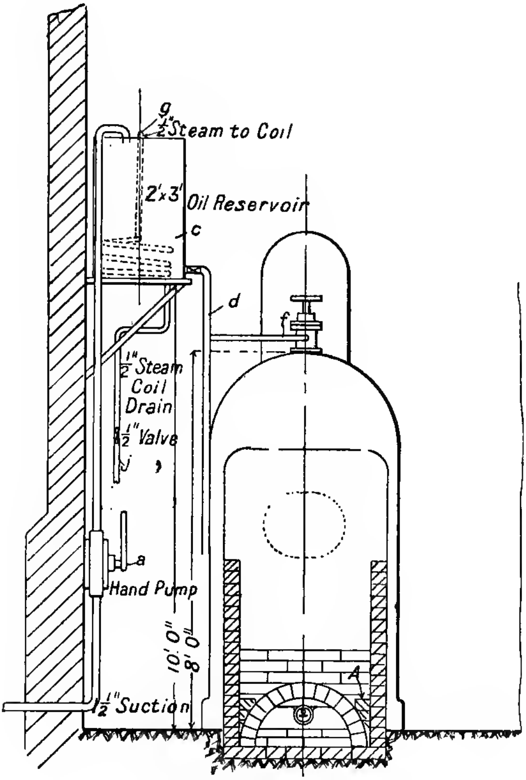


FIG. 26.

PIPE WORK, VALVES, ETC.

In fitting up an oil-fuel installation, particular care must be taken if leakage is to be avoided. Heated fuel oil, compressed air, and lastly, but of most importance, superheated steam requires first-class material and workmanship if their searching qualities are to be effectually checked, and no trace of leakage observable.



Sectional Elevation.

FIG. 27.

It is true, with compressed air, at the low pressure it is used in oil-burning, ordinary wrought-iron pipe will do, if carefully put together, but the stop valves should be of the best quality.

For superheated steam, however, it is useless to erect anything except steel pipe expanded into cast-iron flanges and flanged stop valves. Though wrought-iron screw-jointed pipe may show no leakage when first put into use, sooner or later the steam eats into the joint and destroys the thread owing to the high temperature of the steam; little will be seen issuing from the joint, but a white, chalky substance that forms on the metal makes the leak easy of detection.

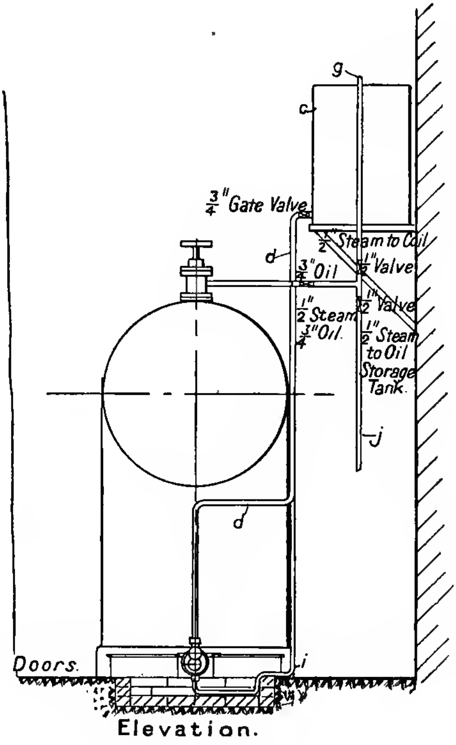
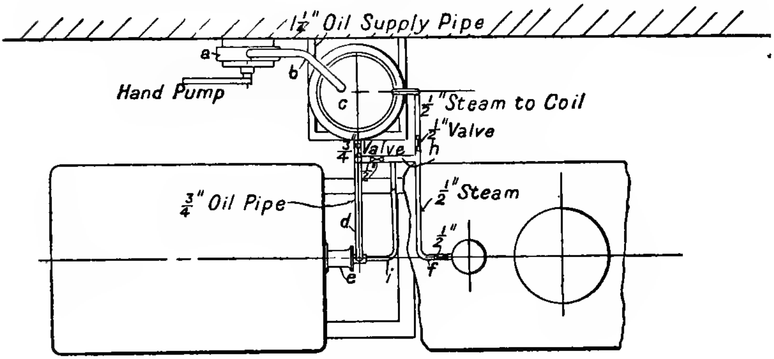


FIG. 28.

The searching properties of petroleum are well known, and heated fuel oil, even at a few pounds pressure, will weep from the minutest hole, or average screw joint. All screw joints should be eliminated without exception, pipe of the best quality only employed, the angles bent with care, and the ends of the pipe carefully expanded into cast-iron flanges. If a flange splits in half during the process, so much the better, as it shows the work is being well done. To join the flanges, leather soaked in hot glue is hard to surpass, but the faces of the flanges must be machined and pulled evenly together with bolts and nuts. Flanged gate valves should be employed in the distribution pipes, as they give a free passage to any fine substance that may pass the filters. With regard to filtering the oil, this depends a great deal on the oil-burning system and the class of burner. In the pressure-jet system, the filtering medium has to be exceedingly fine, and the oil passed through at a high temperature, as the small orifice of the burner easily chokes. Such filters have to be in duplicate, as frequent cleaning has to be resorted to, which cannot be done unless the medium is entirely removed. With the Scarab burner fine filtering is completely done away with, and if a filtering medium with one-eighth of an inch mesh is used, there need be no



Plan of Boiler.

FIG. 29.

fear of choking, as the smallest burner orifice is one-quarter of an inch, and all foreign matter is injected into the furnace and consumed. In the average oil-burning system the choking of filters and burners is one of the chief causes of a falling steam pressure.

It must not be forgotten that the first indication of a stoppage is a falling steam pressure. The obstruction to the passage of the oil may be in the filters, stop valves, or burners, and the fireman must be able to easily examine these items to see that they are clear. On the other hand, the fall in steam pressure may be due to an extra demand on his boilers, but the water-gauge should indicate this cause. Water in the oil may also cause the fault, but if this occurs steam can usually be detected in the furnace. In gravitation feeds the temperature of the oil must also be kept constant, or the flow from the oil orifice will vary, and insufficient oil injected into the furnace without readjustment of the burner. In the pressure-jet burner great care must be taken to maintain a high temperature, or the burner may fail entirely. It by no means follows that a fireman who is an expert at coal firing will be equally successful with liquid fuel: one requires physical strength, while the other requires intelligence, comparatively speaking.

Firing Vertical Boiler.

Figs. 30-33 show a boiler of the vertical type, and the method of firing with the Scarab burner. It is a type of boiler much used by contractors, and is shown with a portable storage reservoir and feed-tank.

Fig. 30 is an elevation showing the general arrangement of the reservoirs and pipe work.

Fig. 31 is a section through the firing aperture.

Fig. 32 is a cross section of the furnace facing the burner.

Fig. 33 is a plan of the furnace, showing the relative position of the oil-feed tank and reservoir.

From the storage reservoir *a*, the oil is delivered by the hand-pump *b* into the feed-tank *c*, from which the oil flows to the burner *f* by the pipe *g*. The steam-pipe *h*, with a branch *i* for heating the coil in the tank *c*, and a by-pass to the oil-pipe *g*, conveys steam to the burner *f*. The whole installation is of extreme simplicity and inexpensive to erect.

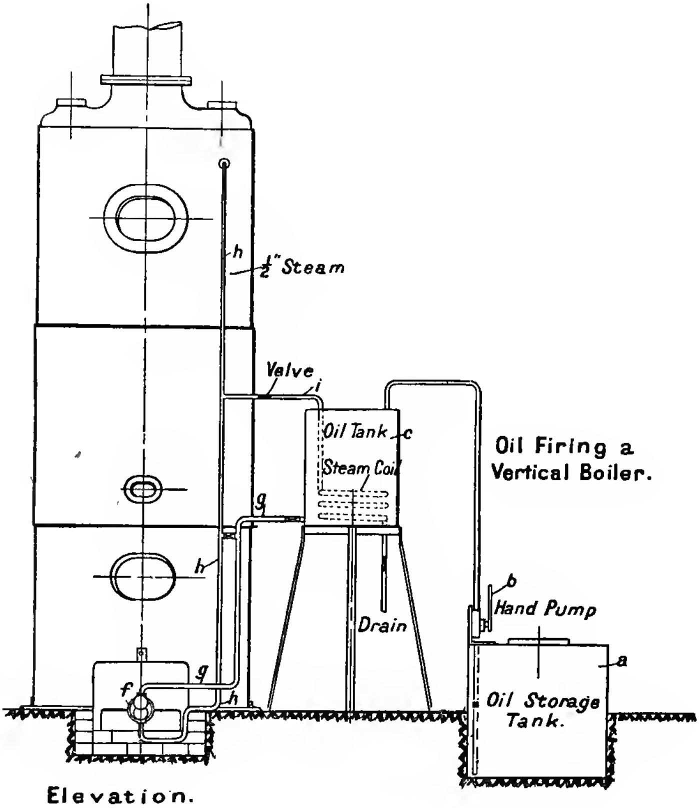


FIG. 30.

The boiler shown is of the usual 16 H.P. type; but with oil firing, the power is increased from 25 per cent. to 50 per cent. When these boilers are well lagged, they are an efficient type, and large sizes are much used in some countries.

There are, of course, many other designs of steam boilers, but the illustrations given are sufficient to show how liquid fuel is applied for steam-raising purposes.

Figs. 34-35 show a design of Scarab burner suitable for the small type of boiler just described. Fig. 34 shows a side elevation, and Fig. 35 the end view. With the exception of some modification in the nozzle and reduced proportions, it does not differ from the burner shown in Fig. 17.

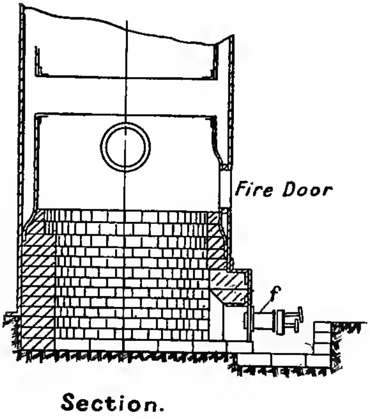


FIG. 31.

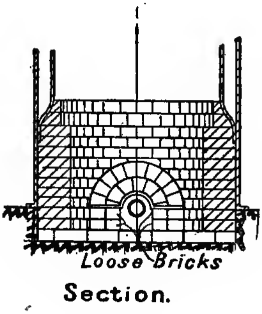


FIG. 32.

SCARAB SYSTEM FOR MARINE PURPOSES.

It must not be thought that because kitchen ranges and steam boilers have alone been dealt with in the preceding pages, that the Scarab system of oil firing cannot be applied for other purposes.

There is practically no form of furnace to which it cannot be successfully applied, provided the essential features have been carefully studied beforehand. In the same way, there is practically *no type* or *grade* of *liquid fuel* that this burner will not burn without any tendency to choke. The viscosity of the fuel oil it was designed to burn is exceptional. With 23 lbs. to the square inch, at a temperature of 40° Fahr., the oil could not be forced through a three-inch pipe.

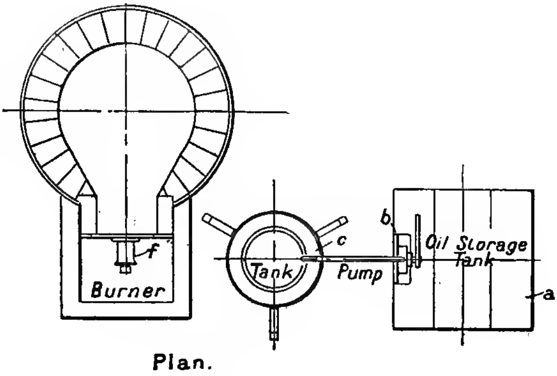
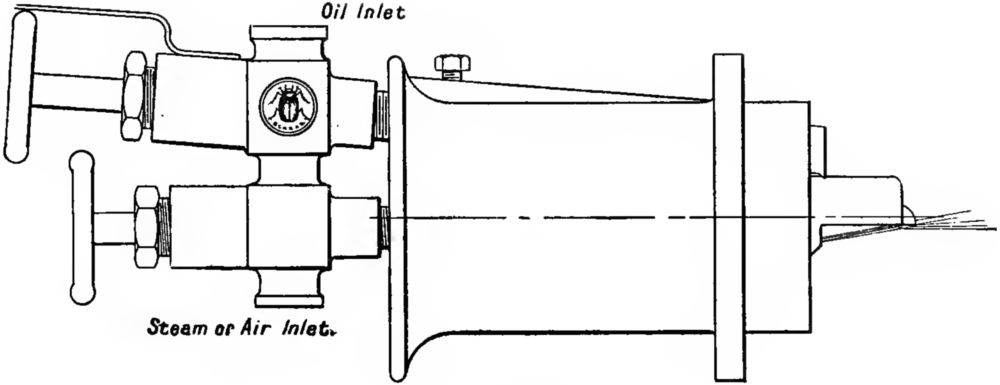


Fig. 33.

At the present time the pressure-jet system of burning oil is used almost exclusively on board ship, as the steam from the oil force pump can be condensed. On the other hand, the mechanical apparatus is complicated, and the burners are not free from the choking tendency. The Scarab burner is economical in the use of compressed air; trials on a large boiler have given good results, and there seems no reason why a rotary compressor on board ship should not displace the force pumps with advantage.

Though a slightly higher efficiency may be attained with compressed air, steam, when used in an economical



Elevation.

FIG. 34.

burner, is in some ways to be preferred. To use steam for the burner, and yet preserve the main steam supply by condensing all the steam used, and not injecting it into the furnace, the burner must be supplied from another source, which, unlike the main boilers, does not require fresh water.

It is open to conjecture that improvements in oil burning for marine purposes lie in this direction, as reliability is of first importance, and the reduction of working parts should be kept in view.

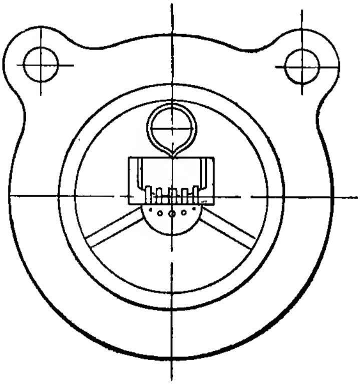

End View.

FIG. 35.

With steam tenders, tugboats, dredgers, and all types of river craft, steam burners may be applied with advantage. In such cases there is no room for duplicate sets of filters and pumps, neither is there the same necessity for preserving the fresh water intact. The very first requirement in such cases is reliability and the necessity of a wide range of power. That is to say, it must be possible to turn the flame down to small dimensions, and be able to open out the burner to full power in a few minutes. The merits of a single burner that will range from 20 H.P. to 200 H.P. for such work are obvious. For very large steamships, where many thousands of horse-power are required, the pressure-jet system no doubt has the advantage, but the cheapest residues procurable in Eastern ports are liable to give a lot of trouble, and owing to the high temperature and high pressure at which the oil must be maintained, there is a certain amount of risk, and accidents have been recorded of a disastrous nature. Oil fuel applied to subsidiary craft increases the power and range of activity, and reduces the time spent in bunkering fuel, to say nothing of the enormous reduction in the labour bill.

A greater fuel economy still would result from installing heavy oil internal-combustion engines, but it is by no means certain that loss of flexibility under way and inability to 'force' the power under special circumstances, such as towing in a stiff gale, or warping out heavy ships from crowded docks, would not prove too much of a drawback and eventual loss to the shipowner.

In many Eastern ports oil fuel will always be much cheaper than coal, and though on tenders and tugboats engaged in intermittent work, and constantly starting and stopping throughout the day, high efficiencies cannot be expected, the saving in expense should be very large when coal and oil are about the same price. Neither should there be any extra repair bill for the boilers, provided the burner has a suitable furnace setting. On the contrary, in this respect there should be a saving in upkeep with ordinary intelligence and care. Solid fuel has been of such universal use for so many generations that liquid fuel is often looked upon with suspicion. Standard boilers and furnaces are not provided with the necessary fittings for burning oil, and shipowners in foreign ports hesitate to have the work done locally, or go to the great expense of engaging special men in England, and purchasing valuable plant to fit up small boats abroad, and it is a common thing to find such boats burning coal when residues can actually be purchased on the spot at a much cheaper rate.

Marine oil-burning plants are a speciality, and those firms who supply them provide their own special fittings adapted to their own burners, and their system is practically without exception expensive to install.

The usual type of boiler is not the most suitable in design for burning oil. It takes too long to convert the coal-burning ship to an oil-burning ship in a foreign port, and there is a real demand for a boiler that can be easily converted, so the ship can leave home ports using coal fuel, and substitute liquid fuel for the coal in Eastern waters. To burn liquid fuel with coal in the same furnace cannot be described as very satisfactory. Only a portion of the economy in labour can be realised. The highest efficiency of combustion cannot be attained. The cleanliness of using oil fuel is lost, together with the constant temperature of the furnace from having to open the furnace door, as it is practically impossible to find room for a mechanical stoker besides a set of oil-fuel burners in the furnace front. If the demand for oil-burning ships increases to any great extent, no doubt a type of boiler and furnace will be evolved that can easily be adapted to liquid fuel by spending a few hours in port, and so prevent the loss of time which at present occurs when a coal-burning ship has to be converted.

Modification in design could also be made with advantage, and probably the great advantages of the water-tube type of boiler would be more realised.

TRANSPORT.

One of the great advantages of liquid fuel over coal is the economy in transport.

To convey a liquid in large quantities over long distances, power is required, and the more direct the application of that power to the work to be done, the more efficiently and cheaply will it be conveyed.

The most direct method known of applying power to convey a liquid is to force the liquid through a pipe by means of a working substance actuating a suitable mechanical apparatus. In other words, by pumping the oil by means of direct-acting pumps.

For oversea transport and for marine use, the oil is simply pumped into the ships' tanks in loading and pumped out when unloading. As a steam pump uses only a fraction of the power required to drive half a dozen steam cranes for hoisting coal from ships' holds, there is a great saving in power, besides the saving in labour.

The handling of coal by mechanical methods has been brought to a high state of perfection ; but a large proportion of hand labour has still to be utilised, and the nature of the material does not permit of that direct application of power which is so easily applied when the material to be dealt with is a liquid, like fuel or crude oil.

Without access to verified statistics, it is impossible to give figures showing the actual saving in cost of handling a thousand tons of coal, compared to a thousand tons of oil ; but when it is borne in mind we are able to commence the comparison by eliminating from 30 per cent. to 50 per cent. from the weight of the oil, according to the purposes for which it is going to be used, it will be understood that in countries such as Italy the saving amounts to a very large figure.

Secondly, the immense saving in cost of rail transport and labour, due to less storage capacity being required, and the ease with which it is handled.

For instance, let us take the case of an average power-house, burning 270 tons of coal per month. Every four weeks, nine 30-ton wagons of coal will be run into the power-house siding. A large gang of men, possibly thirty, or more, according to the time available and quality of the labour, will be required to unload these trucks and stack the coal in the power-house bunkers, from whence it is daily removed to the boiler-house floors for the fireman to feed the furnace.

If oil fuel is used, only six 30-ton tank wagons are required per month to run into the siding. Three or four men attach pipes to the oil-tank, and the oil runs by gravitation into the power-house reservoir. Either a small power pump or pneumatic ejector automatically delivers the oil into the boiler-house feed-tank for feeding the burners, and the fireman's duties consist of regulating a few valves. There are no fires to clean, no ashes to remove, and the manual labour of the boiler-house is reduced by 90 per cent. In supplying locomotives even greater economies could be shown.

ABSENCE OF DANGER.

Though it is well known to those who are accustomed to burn fuel oil that it is perfectly safe to handle, many people are under the impression that there is always a certain amount of danger from fire and explosion in transporting and using this fuel. But the fact is that it is actually safer than coal in some respects, as much higher temperature is required for ignition.

No doubt the idea of 'danger' has arisen from the highly inflammable nature of the lighter products, such as petrol and paraffin, which are universally used by the public, and the greatest care exercised to avoid conflagration. But it is just the very fact of these lighter products being extracted from the crude oil which renders the fuel oil or residue safe to handle. Indeed, one of the principal difficulties of bringing fuel oil into general use has been to devise methods which will produce combustion, and, in culinary operations, means for preventing the cook from extinguishing the fire by means of excessive oil.

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Printed by T. and A. Constable, Printers to His Majesty
at the Edinburgh University Press